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Editorial

PROGRESS and trends in the operating divisions of the production, refining, natural gasoline manufacturing, and pipe line branches of the industry are outlined in this issue — the Annual Engineering Review Number.

Many of the improved methods and practices introduced in recent years are indirectly the result of restrictions imposed on the industry. No industry has profited more by its own mistakes than has the petroleum industry. Over-production of crude oil, for example, led to proration, and proration changed the economic picture. It has made producers conscious of operating costs; more important, it has been instrumental in demonstrating the benefits to be derived from reservoir control.

Lack of proration laws in the State of Illinois led to boom operations in that state. The excess production that resulted, being in proximity to large centers of consumption, caused a shift in drilling, producing, refining, and pipe line operations, and upset things generally. Aside from nullifying the benefits of proration elsewhere, the life of many fields in the State of Illinois will be cut short.

Geochemical prospecting methods are attracting increasing attention. Soil and soil gas analysis have been further developed. These geochemical methods show promise of disclosing structures of low or no relief. It is the first prospecting method used that attempts to indicate oil and gas in place.

Efforts to reduce drilling costs have aroused interest in slim-hole drilling; this interest extends to its possibilities for use in drilling deep wells. Rotating speeds in drilling are also being studied. Investigation of the rates of bit penetration to reveal the importance of the various factors involved may result in changing existing practice.

Some notable advancements have been made in production methods. Pumping from great depths using sucker rods is being investigated. One well in California has been pumped from a depth of 8315 ft. This is believed to be a record. Scientific devices have been developed for determining fluid levels in pumping wells. The ease and dispatch with which fluid levels can be determined are expected to aid greatly in increasing well-pumping efficiency.

Production methods in condensate fields have confronted engineers. Many of the deep high-pressure fields in the future will be of this type and maintenance of pressure in such fields will become a necessity. Studies indicate that a slight reduction in reservoir pressure may involve serious underground losses and so reduce ultimate recovery.

Catalytic processes of oil refining promise to change many of the existing practices. The Houdry process recently announced indicates the possibilities of catalytic processes. Better economic balance between heating fuels and gasoline may be attained. Because of the flexibility of these processes, grades of crude hitherto regarded as unsuitable will be available for refining into high-grade products.

In natural gasoline manufacture there has been a notable increase in the use of refrigerants. Lower temperature is almost a necessity for recovery of propane and butane at nominal pressure. In order to isolate the more volatile constituents, fractionation or stabilization is accomplished at much higher pressures than formerly. Higher operating pressures have brought problems in design and operation. One problem that has been given intensive study is the formation of hydrates, and numerous dehydrating processes have been developed.

There is a continued trend toward high-speed engines connected through gear increasers to centrifugal pumps in main pipe-line stations. Cathodic protection of pipe lines has proved its efficacy, and many improved methods of cathodic protection have been devised.

It is significant that there is an overwhelming trend in the petroleum industry toward the utilization and application of science and engineering skill in the conduct of its operations. So long as this trend continues progress in devising improved operating methods and equipment is assured.

THE Petroleum Engineer

MIDYEAR, 1939

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

Recent Trends and Progress in Refining in California

By WALLACE A. SAWDON

Pacific Coast and Foreign Editor

IMPROVEMENT in the quality of lubricating oils made from western crudes has recently been given inincreased attention by California refineries. To this end refinery equipment has been improved, new plants erected, and old plants extended. New plants for making better motor fuel and special gasolines have also been completed during the last year. The dominant trend is toward increasing the quality of refined products and obtaining greater flexibility in meeting increased demands economically and efficiently.

Union Oil Company's New Phenol Plant

On January 1, 1939, Union Oil Company placed in operation a new phenol-solvent treating unit at its Oleum refinery, marking another significant contribution to the science of modern petroleum refining on the West Coast. This new unit produces maximum yields of high-quality lubricating oil, derived from western crudes, and is expected to assure an adequate supply to meet demands for some time to come.

Requiring several years of careful research, and five months to construct, the new phenol unit embodies many advanced practices. Most of the new features were developed by Union's own research and development staff, headed by Earle W. Gard. Special alloys are used throughout the unit. The use of phenol, which is costly, necessitated special precautions to eliminate waste. One of the many problems encountered during the development of the process was that of recovering the phenol. The system devised to accomplish this involves pre-heating the phenolic extract in appropriate interchangers and subsequent fractionation in a main fractionating column, after which the phenol is separated from the extract oil by distillation in pressure separators, and a vacuum steam stripper. The raffinate, or good oil fraction, on the other hand, carries phenol that can be recovered by simple distillation. By the use of final vacuum strippers on the extract and raffinate oil the overall loss of phenol from the system is reduced to inconsequential proportions.

Because of the nature of the solvent, every effort was made in designing the plant to assure safe operation. The entire system can be closed down, under either normal or emergency conditions, from a central control board safely removed from the plant itself.

Additions to Standard's Richmond Refinery

The largest single appropriation in the 1938 expansion and improvement program for the Richmond refinery of

the Standard Oil Company of California was for the duo-seal treating and dewaxing plant, together with necessary auxiliary facilities for the production of lubricating oils of improved quality. This plant, put into service late last year, cost approximately $2,750,000. This was in addition to the construction of an $800,000 modern crude distillation unit that is contributory to the operation of the lube plant.

Standard's hydrogenation plant built for the production of high-octane aviation gasoline at a cost of $1,700,000 was completed earlier in the year. Other additions included the construction of a plant for the production of cresylic acids at a cost of approximately $130,000 and the installation of an $85,000 plant in which liquefied gas is charged into cylinders supplied to consumers of this product.

Modernization and increase of existing facilities at the Richmond refinery represented an important part of the construction program. Because of the added loads of the new equipment, the power plant constructed about two years ago was found inadequate to supply the total steam and electric power requirements of the plant. Alterations to increase the capacity of this plant were made at a cost of $200,000. Additions costing approximately $80,000 also were made in the polymerization plant that was constructed in 1937. Increased capacity of the plant was necessary to provide for a larger production of "poly" gasoline.

Additions to Richfield's Refinery At Watson

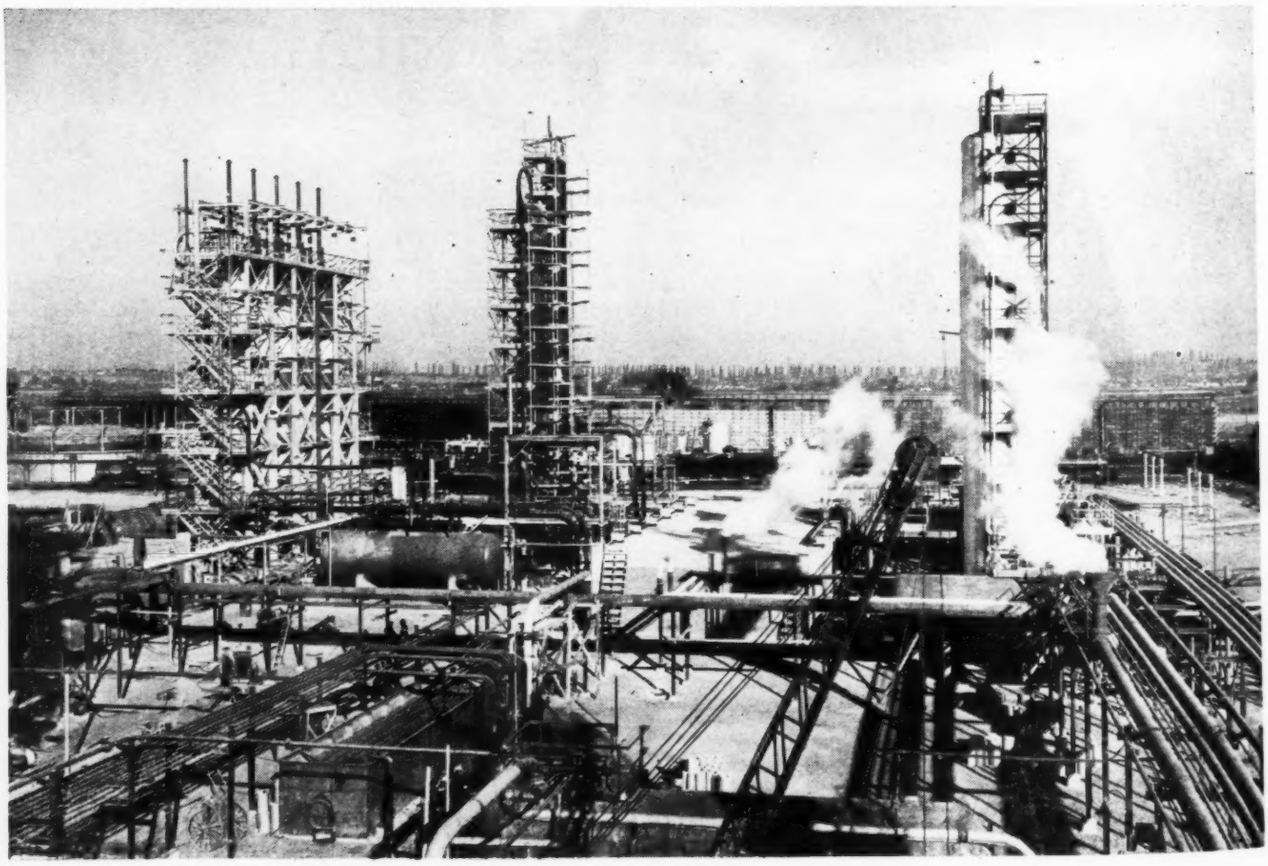
The largest recent expenditure for refinery expansion in California has been in the Richfield Oil Corporation's new plant at Watson, final units of which were placed in operation shortly after the first of this year. Built adjoining the site of the old refinery it is not, however, an extension of the old plant but is an entirely new refinery. Included are two combination topping-cracking units operating in parallel, utilizing a central pump house and control room for both units to coördinate operation. Each unit has a charge capacity of 25,000 bbl. per day of crude oil and reduced crude proportioned as desired.

Each unit includes one double-fired horizontal-type and three vertical down-fired tube-type heaters. Crude oil is pumped through heat exchangers to receive heat from the hot streams coming from the fractionating towers before entering the horizontal heater. The heated oil passes to the flash towers in which the crude is fractionated into 350°-400° F. overhead, a kerosene distillate sidestream, which is stripped, and reduced crude of 15 to 18 deg. A.P.I. gravity. The reduced crude then is returned to the constant load side of the horizontal heater to be heated to approximately 700° F. before it enters the cracking cycle.

The three vertical cracking furnaces of each unit are arranged in parallel and provide for any recycling ratio that may be desired. Seven towers in each unit provide variously for fractionation, separation, stripping, and absorption. In addition to the main plant there is a catalytic polymerization plant. Units are provided for debutanization, stabilization, hydrogen-sulphide removal, dehydration, depropanization, and caustic wash.

Cracked distillate from the cracking plant passes to the debutanizer unit that is of a conventional type operating at approximately 100 lb. per sq. in. The bottoms product in this unit has an initial boiling point of 225° F. and is treated and rerun for sulphur removal in obtaining finished gasoline.

Polymerization plant at Watson, California, of Richfield Oil Corporation



The overhead liquid goes to the stabilizers, operating at a pressure of 200 lb., in which distillation and fractionation result in a butane-free bottoms product. The stabilizer-release gas has to be treated for removal of hydrogen-sulphide before being delivered to the polymerization plant.

The hydrogen sulphide removal system is based on the tripotassium-phosphate process, use of which is licensed under patents assigned to the Shell Development Company. The absorber is 48 in. in diameter and contains 38 bubble plates and one demister tray. The initial H_2S content varies between 2000 and 2500 grains per 100 cu. ft., and mercaptans, calculated as equivalent H_2S, from 100 to 250 grains per 100 cu. ft. The volume of gas ranges from 2,000,000 to 3,000,000 cu. ft. per day, varying according to cracking and reforming operations. The extracted hydrogen sulphide is burned in one of the refinery furnaces.

The treated gas is dehydrated to eliminate any phosphate solution carryover and then goes to the poly plant. One section of this plant is used for producing polymerized gasoline and for stabilizing it to required vapor pressure; the other section is for reactivation of the catalyst. Principal equipment in the former section includes a process heater, five catalyst towers in series, water separator, condenser and receiver, and polymer stabilizing equipment. The equipment in the latter section includes a flue-gas generator, flue-gas scrubber and superheater, the last serving to superheat both the flue gas during burning of the catalyst and the steam during the hydration of the catalyst. Each of the towers is taken out of service periodically for reactivation.

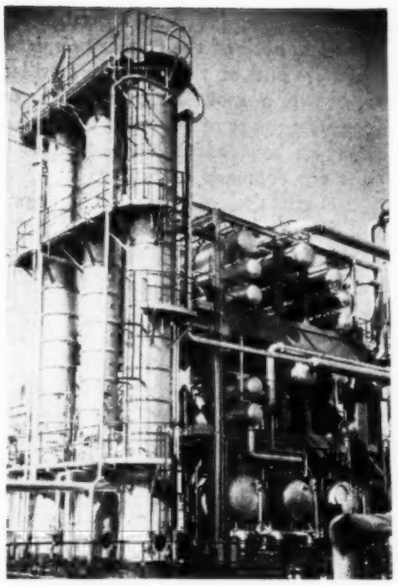
Flow from the catalytic polymerization towers is through a depropanizer column and then through the caustic wash in which approximately 75 percent of the mercaptans present in the blend is removed to reduce the load on the sweetening system.

Electrical Equipment in Watson Refinery

Because the use of steam for powering prime movers in the new refinery would require extensive additions to the existing boiler plant, the use of electricity was decided upon for the Richfield refinery at Watson.

It was estimated that the total load (including that of the older plant) would be approximately 14,000 hp. if electricity was employed for all drives. The old transformers and switching gear had a capacity of only 3000 kw. so considerable expansion and rehabilitation of the refinery substation was necessary to serve the increased load of 9000 kw. The high load and power factors combined with large kw-hr. consumption will result in an average cost for power not exceeding 0.6 cent per kw-hr.

Electric power lines enter the plant at a potential of 11,000 volts. This voltage is stepped down through nine 1000-kw. transformers to 2300 volts. The feeders from the transformers to the main substation are equipped with current-limiting reactors, the use of which greatly reduced the cost of modernizing the electrical layout. It is believed that this is the first installation of automatic gear, reverse-current protection on feeders, and current-limiting reactors in a refinery on the Pacific Coast.



Union Oil Company's new phenol solvent treating plant at its Oleum refinery

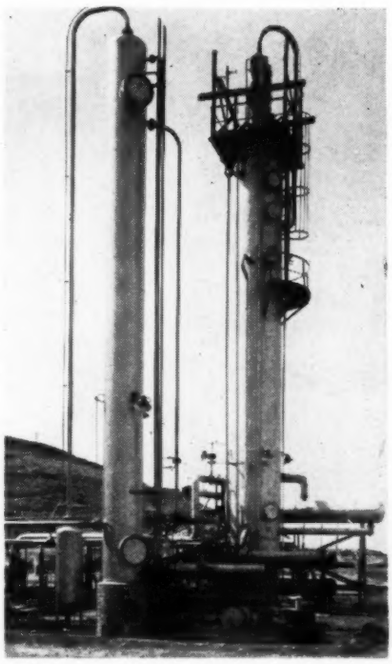
In the combination crude topping and cracking, debutanizer, stabilizer, and polymerization plants the electrical equipment is explosion-proof throughout. All motors ranging in size from 1 to 250 hp. are of Class 1, Group D, construction to obtain underwriters' approval for installation in hazardous areas. All motors are equipped with across-the-line starters, oil-immersed disconnects situated in a concrete switch-room, and explosion-proof start-stop push buttons.

Of outstanding interest are two 1000-hp. inert-gas-filled induction motors that are the first of their kind and are the largest motors used in refinery operations in California. They are the first 1000-hp., two-pole, across-the-line starting motors ever manufactured and are the only CO_2-cooled motors in the world. These motors are direct-connected to the main heater-feed pumps (one on each combination unit), which circulate oil through the coils of the cracking heaters at rates as high as 80,000 gal. per hr. The explosion-proof feature is obtained by maintaining an atmosphere of CO_2 gas within the motor housing, at a pressure slightly above atmospheric, to keep explosive gases from entering. The inert gas is cooled by contact with water coils contained in the motor housing.

The shafts in these large motors are extended at each end. One end is coupled directly to the heater feed pump, and the other end is coupled to a standby steam turbine. The turbine automatically picks-up the load when the speed decreases to 150 r.p.m. less than the electric motor speed and continues to drive the pump. Such an arrangement maintains the units "on stream" during brief power interruptions and permits a gradual shutdown in case of a prolonged electric power failure. The starters for these 1000-hp. motors are conventional oil-immersed, across-the-line magnetic starters of 50,000-kva. rating. Conventional start-stop push buttons also control these motors.

In case of a complete power failure within the refinery, a steam-driven gen-

New hydrogenation plant of Standard Oil Company of California at Richmond



erator automatically goes on the line. This generator has sufficient capacity to supply power to instruments, motor-operated valves, emergency lights placed at important points, and independently-driven oil pumps lubricating the 1000-hp. heater-feed pump motors.

There are three air compressors in the compressor plant, serving the new refinery operating units. The main 3000 c.f.m. and supplementary 750 c.f.m. compressors are operated by 600-hp. and 100-hp., unity power factor synchronous motors, respectively. The third compressor, which is used to supply instrument air, is operated by a 20-hp. squirrel-cage motor. The large motors are controlled by standard synchronous motor starters but the small motor has a conventional magnetic starter with push-button control.

There are two 400-hp. and two 250-hp., 80 percent power factor, synchronous motors having direct-connected exciters, pumping water for the new units. Equipment for these motors includes push-button control, synchronous starters, and oil-immersed disconnect switches.

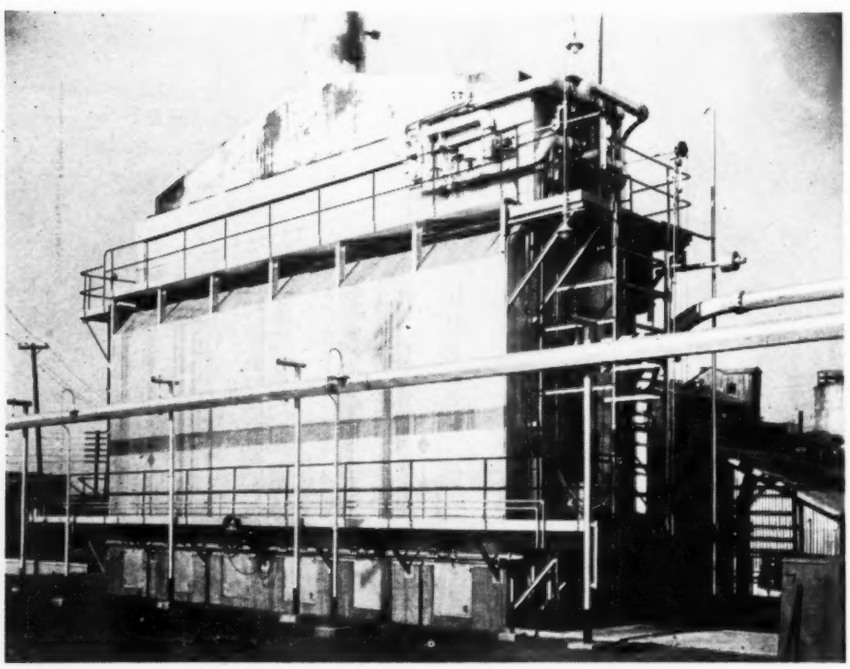
The use of 80 percent and unity power factor synchronous motors in non-hazardous area has increased the overall plant power factor to almost unity. The power factor prior to the modernization of refinery equipment ranged from 82 to 85 percent.

Advanced Stabilization Unit

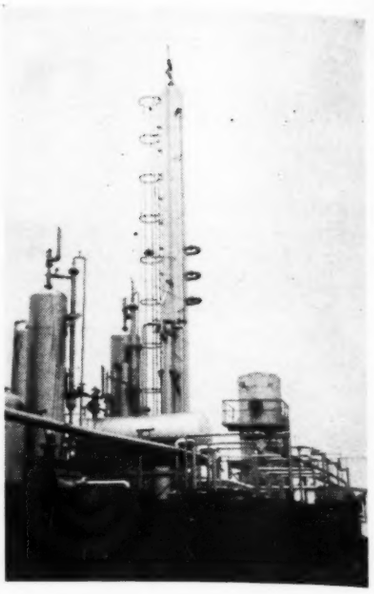
Results of exhaustive road tests conducted by Hancock Oil Company, prompted the decision that more attention should be given to thorough stabilization both of the primary straight-run cuts and of the pressure distillate to obtain a more satisfactory motor fuel. The range of previous test standards was believed to be inadequate to meet the demands of modern combustion-engine design, climatic conditions, and driving habits. Using this concept as a foundation, stabilizing equipment was designed to attain the objective.

The fractions comprising the primary cut from the crude oil distillation are introduced into a fin-type exchanger in which the heat from the primary column bottoms is sufficient to increase the temperature of the charge stock to 175° F. Troublesome light fractions, vaporized at this temperature, pass overhead for subsequent stabilization. In the primary column, a reduction of from 3 to 4 deg. A.P.I. is obtained and the bottoms are used as a base stock for premium gasoline. The overhead from the primary stripper enters a floating-head tube-and-shell vapor condenser, in which it is reduced in temperature before it is passed to an accumulator.

The pressure distillate stripper functions in the same manner as the atmospheric distillate unit and the vapor condenser, but having virtually twice the heat-transfer capacity. The bottoms from the pressure-distillate stripper are of proper volatility for blending into commercial gasolines, after gums and sulphur are removed. In the accumulator the overhead from the stripper and the product from the first operation combine to form the charge stock for the final stabilizer.



Heating unit of Union Oil Company's new phenol solvent treating plant

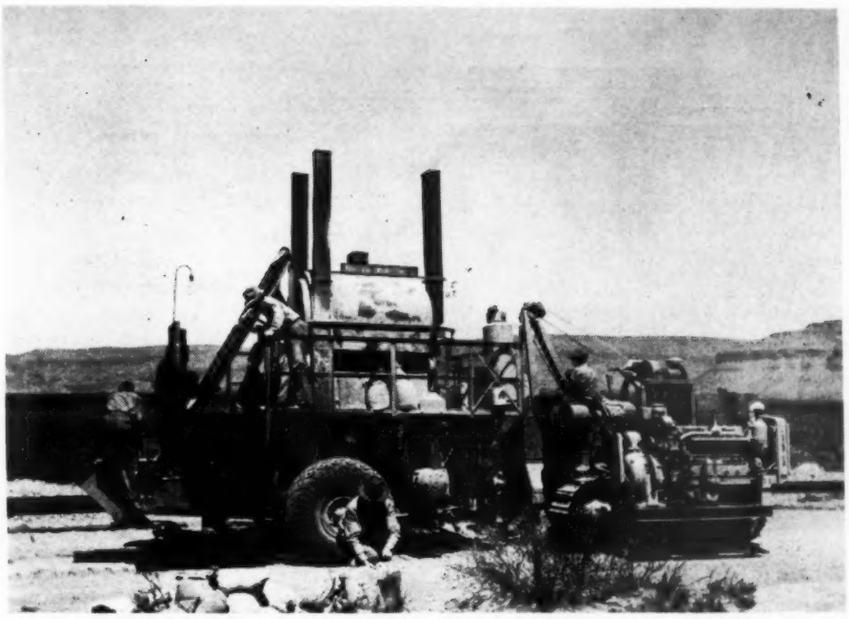


New stabilization plant of Hancock Oil Company of California at Long Beach

The charge is fed to the final stabilizer through one of three connections equally spaced on the column, so that the entrance can be made at the point best suited to the nature, temperature, and volume of the charge stock and to the specifications required for the end product. The main stabilizer column is 30 in. in diameter by 52 ft. 9 in. high, and is equipped with 30 bubble trays on 18-in. centers. The liquid flowing down the stabilizer column is stripped of its propane and lighter constituents by the ascending vapors generated in a reboiler at the base of the column. During the stripping process in the lower half of the stabilizer some desirable constituents such as butanes, pentanes, etc., are vaporized. These are returned to the finished product by the use of reflux produced by condensing propane passing overhead from the tower.

The finished product is taken from the base of the reboiler at a temperature of approximately 250° F., thence to the stabilizer interchanger for further transfer of heat to the stabilizer feed. The end product is then cooled to a temperature sufficiently low to avoid loss in storage.

Equipment used to clean, coat, and wrap a pipe line in a single operation



A PETROLEUM ENGINEER EXCLUSIVE FEATURE

Advancements and Trends in Pipe-Line Construction, Maintenance and Operation

By FRANK H. LOVE

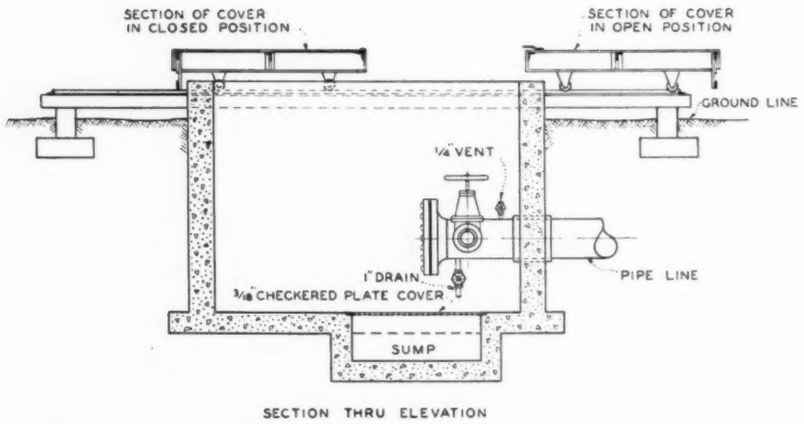
Managing Editor

MAINTENANCE of equipment and low installation and operating costs have characterized pipe-line practices during the last year. Economy in construction of pipe-line systems, which takes into account the laying of the gathering line and the trunk line, and the erection of field and main-line stations, has made itself manifest in several ways. Utilization of high-carbon steel pipe having light wall-thickness has lowered the investment in line pipe and as a consequence has reduced the overall cost of constructing a line. Portable field pumping equipment and semi-automatic stations have continued to predominate in new installations and in many instances have replaced the more obsolete types of equipment already in use. Main-line stations continue the trend to the use of high-speed, gear-type units. As an essential part of operating economy most companies maintain systematic control of viscosity and of the general condition of lube oil by periodic checking. Frequent analyses of jacket water is another common requirement. The companies following such practices have been rewarded by minimum bearing losses and fewer cracked cylinder heads. Operating efficiency is improved, also, by the practice of making a periodic check on all pressure gauges, thus maintaining uniform operating pressures throughout the system. Increased use of cathodic protection units indicate further the confidence being placed upon them as a means of protecting pipe-line property.

Main-Line Station Design

The new oil pipe-line stations constructed during the year were for the most part equipped with high-speed gear-type units, continuing the trend to that type equipment for oil pumping. The greatest number of new stations was erected in the active Illinois Basin area. Stations were constructed by the Central States Pipe Line Company at Salem, Clay City, Flora and Xenia. At Salem two 500-hp., 400-r.p.m., air-injection Diesel engines were installed. These are connected through gear increasers, at a ratio of 9:1 to 3600-r.p.m. centrifugal pumps having mechanical seals. The gears are of the new steel-case type developed particularly for pipe-line service when high ratios are required. At Clay City a single solid-injection engine rated at 900 hp. at 265 r.p.m. has been found adequate for the work required. The engine is connected to a centrifugal pump through a gear increaser at a ratio of 13½:1. At Flora and Xenia, which are intermediate stations, the equipment is of a somewhat different type. Here light, high-speed Diesel engines, such as are often used in field-pumping service, are used. Nine 95-hp. portable units drive 4½-in. by 10-in. reciprocating pumps through step-down gears. This equipment, although light, is capable of 24-hr. service and is used extensively for "stop-gap" service when it is necessary to attain peak capacity rapidly. The equipment represents low investment cost and has demonstrated its ability to give highly efficient pumping service. The units are unitized and each is protected automatically from excessive temperature, low lube pressure, and overspeed.

A feature of the Central States Pipe Line Company's system is the provision made for cleaning the line pipe. Scraper traps have been installed at stations



Scraper trap installed on system of Central States Pipe Line Company in Illinois

and at all junctions where the line size changes. The traps are designed to be structurally sound, which has not always been true in the past. The concrete pit, situated beneath a blind flange, receives the debris and from here it drains into a sump. The interior of the traps is easily accessible. The steel cover is divided and each section slides horizontally on a rail.

The Texas-Empire Pipe Line Company constructed new stations at Lawrenceville and at Casey.[1] These stations also make use of high-speed pumping equipment and gear increasers. At Lawrenceville there are two centrifugal pumps connected through speed-increasers to convertible Diesel-gas engines. The engines are rated 300 hp. at 400 r.p.m. and the gear ratio to the pumps is 7¾:1. The engines are 6-cylinder, 11½-in. by 13½-in., 4-cycle units having a capacity of 24,500 bbl. each at 3100 r.p.m.

The pumping equipment at Casey station is similar to that at Lawrenceville. The 6-in., 4-stage centrifugal pumps have a capacity of 1000 bbl. per hour each under a head of 1160 ft. operating at a speed of 3550 r.p.m. The two engines are rated at 350 hp. at 225 r.p.m. and the speed increasers are designed for an increase from 225 to 3600 r.p.m.

When the Rocky Mountain Pipe Line Company, subsidiary of the Continental Oil Company, constructed a line from the Lance Creek field, Wyoming, last fall, two stations were erected, one at Lance Creek and one at Cheyenne.[2] Equipment at the former consists of a 300-hp., 3-cylinder, angle-type, 2-cycle gas engine connected to a 4¾-in. by 24-in. pump. At Cheyenne a 360-hp., 5-cylinder Diesel engine connected to a 4¾-in. by 24-in. pump was installed.

[1] "Pipe Lines Serving New Fields in Illinois", by H. Lee Flood, *The Petroleum Engineer*, March, 1939.

[2] "Construction Features of Pipe Line in Rocky Mountain Area," by Frank H. Love, *The Petroleum Engineer*, October, 1938.

Arresting Pipe-Line Surges

Pressure surges in the discharge piping of reciprocating pumps have long been a problem to pipe-line operators. The method devised by one pipe-line company for alleviating these surges has proved of widespread interest.[3] The method involves the use of crossover or equalizer lines interconnecting the discharge lines of the pumps. In making the first test a 4-in. line was used to interconnect the discharge lines of two 15,000-bbl. capacity, 24-in. stroke duplex pumps. This resulted in the reduction of the range of pressure variation from 745 lb. to 95 lb., despite the fact that the 4-in. equalizer line contained six right-angle turns. Satisfied by these results, that the equalizer line provided a practicable means of arresting pressure surges, tests using a larger line were believed justified. This test involved the use of a 6-in. line interconnecting the discharge lines of one 20,000-bbl. and three 12,000-bbl. capacity, 24-in. stroke duplex pumps. The ultimate result of this test was the reduction of the surge pressure to a maximum of 50 lb. The results of these tests prompted three permanent installations, one at a three-unit station and two at a four-unit station. The results of the permanent installations were even more satisfactory than those obtained in the preliminary tests, 40 lb. being the maximum surge.

In explaining the manner in which the crossover or equalizer line accomplishes its results Harshman summarizes:

"(1) It permits averaging the flow variation from the discharge line of one pump to that of another.

"(2) Reduces the intensity of pressure waves due to dampening or diffusing effect by splitting the discharge stream."

The advantages of such an arrangement over the use of air chambers or alleviators are pointed out as being:

"(a) Greater safety. No high-pressure air required with its ever-present explosion hazard.

"(b) Simplicity of operation. No attention required after opening valve into crossover line when closing pump by-pass.

"(c) Low maintenance cost.

"(d) Less investment required than to equip each pump with air chamber or alleviator."

The disadvantages are given as:

"(a) All units cannot be connected at stations where more than one grade of crude oil is pumped.

"(b) Not as efficient in cushioning surges as air chambers; however, pressure variations are reduced to within safe operating limits."

[3] "A Practical Method of Arresting Pressure Surges in Discharge Piping of Reciprocating Pumps." by J. B. Harshman. Paper presented at Oil-World Exposition, Houston, Texas, April 25, 1939.

Field Pumping Practice

Portable pumping units and semi-automatic stations have almost entirely replaced the heavier type equipment used in former years. These units represent a low installation and operating cost, and consequently result in a minimum per-bbl. cost for pumping. Their value in stripper areas, in prorated fields, and in new fields before the volume of oil available is sufficient to justify a more permanent type of pumping means has been definitely established.

Portable pumping equipment is available in a number of different types—reciprocating, rotary, or centrifugal pumps driven by single- or multiple-cylinder gas or gasoline engines or by electric motor. The power is transmitted from engine or motor to pumps by shaft and coupling or by flat or V-belts. Methods of portability vary. Units can be mounted on skids, four-wheel trailers, two-wheel or semi-trailers, or truck for transportation from one location to another.

Moore[4] describes one type of low-

[4] "Maintenance of Portable Pipeline Field Pumping Unit," by N. G. Moore. Paper presented at Oil-World Exposition, Houston, Texas, April 25, 1939.

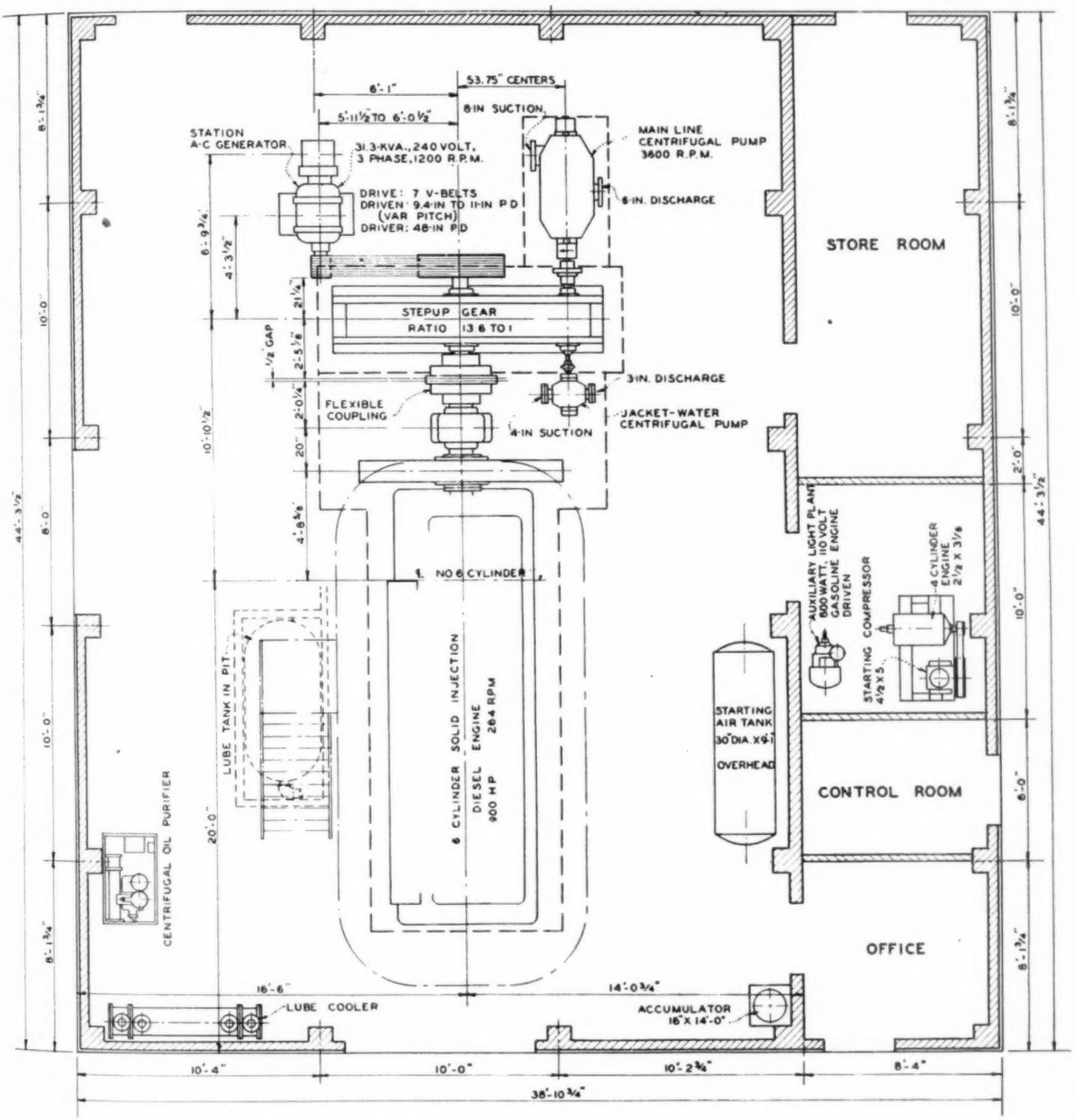
pressure portable unit used extensively by his company in the East Texas field. A 6-in. by 6-in. duplex reciprocating pump is direct-connected to a 30-hp., 4-cylinder industrial engine, the unit being mounted on a two-wheel trailer without springs. The manufacturer's skid base is utilized as a trailer frame. Pump connections may be made using oil-cargo hose; the suction hose should be 200-lb. test and the discharge, 450-lb. test. The end of each hose should be provided with unions having hand grips on the bonnet, as this type union makes possible rapid connecting and disconnecting. On location they can be connected or disconnected in ten minutes if line connections are available. The units are equipped with combination gas/gasoline carburetors, oil filters, air filters, high-temperature cut-out, and low-oil-pressure cut-out. Their pumping capacity is 275 bbl. of oil per hr. against a pressure of 150 lb. This pumping unit is used extensively in prorated fields or on leases that have only one or two wells to be pumped.

Portable equipment has also been used to good advantage in new fields when a temporary station is desirable until certain factors can be determined relative to the selection of a site and preparation of an economical design for a permanent station[5]. These serve their purpose well until such time as they are replaced by a permanent high-pressure station.

These latter, insofar as possible, are designed "for simplicity, low investment, and high salvable value." A station in the Fitts Pool, Oklahoma, typical of this type contains the following equipment: six 300-hp., 625-r.p.m.,

[5] "Trend in Pipe Line Practice," by William G. Heltzel. Paper presented at Oil-World Exposition, Houston, Texas, April 25, 1939.

Layout of a recently constructed main-line station, illustrating the trend in modern design



8-cylinder vertical gas engines that can be converted to Diesel engines connected through gear increasers to six high-pressure, 3600-r.p.m. centrifugal pumps; two electrical generators, belt-driven from the shaft of the engine; two 18,000-bbl. floating roof tanks; one 10-in. by 18-in. suction pump serving a group of lease tanks situated on low ground and used in connection with a gravity system; six high-pressure heat exchangers installed in the crude oil discharge lines; a simple system of station lines, and a sectional manifold piping system. The main station building is of sectional steel construction, 32 ft. by 124 ft.

Semi-automatic stations have come into extensive use also to solve a problem presented in the gathering of limited quantities of oil in a stripper field, which problem likewise exists in small, scattered, prorated fields. To cope with the factors incident to such conditions, which tend to create high operating and maintenance expense, the semi-automatic station is now generally used. This type station is also being installed to replace gathering stations containing obsolete equipment.

A typical installation consists of[5]: "An induction type electrical motor; a completely enclosed piston type pump; a V-belt drive; weather proof housings for the electrical motor and the drive; self-oiling systems for the motor and pump; suction and discharge piping fabricated from seamless pipe and forged steel fittings; and a small building used to house all the instruments and electrical control equipment."

The pumping unit may be installed with or without a building. The principal automatic features consist of starting and stopping the motors by means of an electric time switch clock. A high-pressure switch is also used sometimes that stops the motor when pumping pressure becomes excessive. If power interruption occurs, an open-phase relay equipped with a time-delay disconnects the power for a period of 20 minutes and prevents the motor and compensator from burning-out.

Pipe-Line Construction

In constructing the numerous pipe lines laid during the year conventional methods were employed for the most part. One interesting development, however, has been the perfection of a machine for coating and wrapping pipe in one operation, performed, if desired, while the line is in operation. One such machine[6] is of the hopper type and has a semi-doping shoe. The hot coating material is poured into a hopper, from which it flows over the pipe. Coating not adhering to the pipe is circulated from a drip-pan back to the hopper by a rotary pump. The pump is driven by a small gasoline engine, which also provides the power to propel the machine along the pipe, and drives the arms and spools behind the machine. This machine weighs approximately 600 lb.

Another machine, larger and heavier, has been designed that cleans, coats, and wraps the pipe in one operation. This equipment has recently been used in reconditioning an 8-in. line of the Pasotex Pipe Line Company near El Paso, Texas. The work was performed while the line was in operation. One of the accompanying illustrations shows the machine in use.

The two instances here discussed were on jobs involving the reconditioning of old lines; however, the equipment could also be utilized to coat and wrap new pipe.

Cathodic Protection

The value of installing cathodic protection on pipe lines is no longer a moot question. Enough pipe-line companies have had cathodic protection units in service for a sufficiently long period of time to establish from their leak records that this type of protection is actually accomplishing the work for which it is intended. The value of such units being established, activity the last year has been in its application to sections of pipe lines not already so protected, and in the adaptation of existing equipment or the devising of new equipment to meet specific needs.

The principal types of units are: (1) rectifier unit, obtaining electricity from a power line, (2) motor-generator set, obtaining power from the same source, (3) gas-engine-driven generator, (4) wind-powered unit, and (5) rotary engine utilizing gas pressure, driving a generator. In areas close to sources of electric power the installation of cathodic protection units is a relatively simple matter. In isolated areas where it is impossible to give the units frequent service, difficulties sometimes arise. In such areas wind-driven generator units and gas-engine-generators are used. The latter, obviously, can only be utilized on gas lines. Corrosion and electrolysis engineers, in solving their individual problems, have done much to advance this relatively new phase of pipe-line engineering.

During the last year engineers of the Houston Pipe Line Company, desiring a gas-engine-driven unit that would require little attention so that it could be used in isolated areas, developed air-cooled engines that have proved efficient[7]. The company had had in operation for several years water-cooled gas engines driving cathodic protection units. These units were situated within a limited area and could be serviced daily and as a consequence had given about 97 percent continuous service. From these the idea for developing the air-cooled engines was born. The basic idea is that by cooling the oil the entire engine can be cooled. Initially, two units were constructed, an 8-kw. and a 1-kw. capacity. In making shop tests two things were found to be wrong with the conventional air-cooled unit: (1) excessive head temperature, and (2) excessive crankcase temperature. In the case of the small unit, the entire assembly was placed on a large hollow casting. This casting served as a mounting base for the engine, generator, and control panel; it held six gal. of lubricating oil, displacing the 4-pint crankcase, and it was a good heat radiator when mounted on 4-in. by 6-in. sills. The oil-heating problem was thus solved and engine-head temperature was also lowered. In the case of the 8-kw. unit, it was obvious that it would be difficult to fabricate a casting large enough to serve as a base and at the same time serve as a crankcase, and, as no suitable oil pump could be installed on the engine, it was necessary to devise a separate oil-conditioning unit. Both of these units have proved satisfactory in operation.

An interesting cathodic protection installation was made recently by a major pipe line company to protect the tanks at one of its pipe line station tank farms. Motor-generator units were installed and to date have been giving satisfactory service. As this is the first attempt to protect tanks cathodically on such an extensive scale, officials of the company are keeping a close check to obtain an accurate record of performance. The success of this undertaking may result in the more general use of cathodic protection for like purposes.

[6] "Features of Pipe Line Reconditioning Work," by Frank H. Love, *The Petroleum Engineer*, September, 1938.

[7] "Air-Cooled Stationary Engines Remodeled to Permit Cooling of Lubricant," by Dave Harrell, *The Petroleum Engineer*, January, 1939.

Progress and Trends in Production Practice

By H. LEE FLOOD
Associate Editor

If production progress from year to year were measured solely by the number of entirely new devices or methods appearing during a year's period there would be relatively little to report. Fortunately, however, truly substantial progress is gauged more by the application of old methods to new problems and by further study and refinement of processes and practices already existent.

One outstanding feature of all present-day production problems is the tendency to reduce all studies of equipment selection and choice of methods into terms of dollars and cents. This apparently obvious statement is more important than it might seem. Not always has it been possible to weigh relative values of the various elements of production accurately enough to permit their expression in terms of money. We are not far removed from the time when production methods and equipment were selected on the basis of which "looked" the cheapest. The haphazard methods of producing oil have been displaced in most instances by a thorough, exacting study of each element comprising the general production program.

This transition has not occurred overnight nor has it been evolved entirely "on paper". Back of nearly every highly-involved method of studying completion practice, well performance, equipment selection, and production control are years of painstaking work —thousands of man-hours of laborious effort expended in experiments, calculations, observation, and analysis of data. The total knowledge and experience gained through the years is being used to advantage in attacking and solving new production problems that are presented in newly discovered areas and in older fields in which the characteristics alter as the reservoir becomes more nearly exhausted.

Studies of Subsurface Mechanics

Too often in the past, research in the laboratory and in the field involving a study of formation characteristics, behavior of fluids "in place", and other factors pertaining to subsurface conditions in oil reservoirs has been dismissed by many "practical" oil men as being too technical and vague to be of much value in solving day-to-day production problems. To the men and companies who have devoted time and money to research in the realm of subsurface physical and chemical action much credit is due. Whether fully recognized even today, the knowledge gained in these researches has formed a substantial basis upon which many of the existing practices accepted as commonplace have been developed.

Research in the laboratory and in the field has been continued during the last year, in the effort to learn more of the mechanics and physical characteristics of the actions occurring underground as oil and gas are removed from the reservoir. One of these studies[1] completed during the year represents an analysis of the extent to which oil displaces water in its migration from its source beds to the reservoir rock in which it is finally trapped. It was found that as the water saturation of the sand exceeds approximately 15 percent of the pore volume, the permeability of the sand to oil decreases rapidly. Sands having water saturation as high, however, as 40 percent were found to produce large volumes of oil.

Added knowledge of the complex behavior of hydrocarbon systems occurring underground has been gained during the year. A paper[2] presented before the A.P.I. in November, 1938, disclosed the results obtained in a study of fluid mixtures from flowing wells in the San Joaquin Valley, California. It is brought out in the paper that determinations of physical behavior of "dead" crude oils to which varying quantities of gas of constant-composition have been added should be applied with caution.

Condensate Production

Probably no phase of oil production since the introduction of gas-lift methods in the early twenties has created as much interest as the operation of condensate wells. It is probably more accurate to say operation of condensate projects because developments during the last year indicate that a necessary part of efficient condensate production is an adequate plant for processing and returning the stripped gas underground.

Return of gas underground has, for a number of years, been viewed apathetically by a few operators who are producing oil of normal characteristics. This "take it or leave it" attitude has been dispelled rather abruptly since the discovery of condensate reserves. An operator in a condensate area must maintain reservoir pressure or wake up some day to find his wells producing only dry gas, the condensate content having been "lost" underground as a result of premature condensation in the sand.

Considerable "mystery" surrounds the development of condensate projects at the present time. There has been a certain amount of confusion among the majority of oil men concerning the exact nature of the phenomena of retrograde vaporization and condensation. Considerable material is available in literature on the subject, however, so that it should be possible for anyone vitally interested in the subject to gain at least a working knowledge of retrograde phenomena insofar as they pertain to condensate production. A bibliography was included in a paper[3] on condensate production presented recently.

In this paper the authors state that:

"Many problems involving technique and practice have been solved during development work on the condensation processes * * * Controlled stage separation has been effected as a means of fractionation and color control; controlled rate of well flow has been utilized for the same purposes; calculation of the super compressibility of metered gas has been verified by plant scale test; hydrate formation has been studied and methods developed wherein its objectionable formation has been eliminated; test methods have been de- of establishing plant control, other test methods have been developed whereby a strange distillate-bearing gas veloped that provide excellent means may be subjected in the field to plant conditions of recovery and the plant recovery forecast to within 2 percent."

In another paper[4], it is stated: "Like the production of natural gasoline, the recycling of gas in distillate pools is an affiliated producing enterprise. The re-

[1] "Influence of Oil Flow on Water Content of Sands," by Nico Van Wingen. Paper presented at A.I.M.E. Meeting, San Antonio, Texas, October 5-7, 1938.

[2] "Solubility Relations and Volumetric Behavior of Three Gravities of Crude and Associated Gases," by J. E. Gosline and C. R. Dodson. *A.P.I. Drilling and Production Practice*, 1938.

[3] "Condensate Wells — Completion and Recycling Operations," by E. V. Foran and P. C. Dixon. Paper presented at Spring Meeting, Southwestern District, A.P.I., San Antonio, Texas, March 17, 1939.

[4] "Recovery of Condensate from Distillate Wells," by Emby Kaye. Paper presented at Spring Meeting, Southwestern District, A.P.I., San Antonio, Texas, March 17, 1939.

cycling operation is considered mandatory, not only to prevent the waste of gas but is the only means known in the present development of the art by which substantially all of the condensables in the reservoir can be recovered. Already methods have been developed to recover the condensate more efficiently than in the past. Recent technological advances, together with plants in operation or under construction, point the way to further improvements to the end that waste will be reduced or eliminated in a phase of the industry which is already producing more condensate than is manufactured in all of the natural gasoline plants in the country."

Aside from the entirely new production problems that have been ushered in by the development of condensate pools, the new phase of production has made it necessary to devise new methods and instruments for testing and evaluating condensate reserves as a preliminary step to designing equipment and facilities in connection with production of these reserves. It is essential that testing, at least sampling, be conducted in a manner that will preserve the true content at the high pressure that prevails within the formation.

A recent paper[5] describes the methods used by one company in studying condensate. A description of the apparatus used by the engineers of the Texas Railroad Commission was included in data presented at the commission's hearing on condensate wells[6]. Other data presented may have an important bearing upon the commission's regulation of condensate production.

Recycling plants in conjunction with condensate well production are becoming more numerous as known condensate reserves are further developed and as new pools are discovered. For condensate producing operations in the Stratton field, Southwest Texas, a recycling plant was installed and completed during the latter part of 1938[7].

Pressure-Maintenance and Repressuring

Pressure-maintenance and repressuring, two closely related types of efficient production practice, have made consistent gains during the last year. A greater number of operators are realizing the logic of conserving gas, the one medium that is most easily available for forestalling the day when artificial lifting methods must be employed.

Better and more efficient practices are observed in the recent application of pressure maintenance by two of the major companies operating in the Illinois Basin[8]. The Carter Oil Company, operating principally in the Loudon area (in Illinois), started returning gas to the two producing formations in the field shortly after the first of this year. Controlling virtually all the acreage in the Loudon pool, the company is in good position to develop what may become one of the best examples of an efficient gas-drive yet attempted. Because of the slow initial rate at which gas is being returned to the formations, it is not expected that any material increase in *rate* of production or in gas-oil ratio will be obtained. The principal objective of the project is to retard materially the rate of pressure decline and, by avoiding channelling and other injurious effects, to create an efficient gas-drive. An important key to the success of the project is the Shuler pattern of well-spacing in which a well situated centrally serves as an input well from which gas is expected to drive the oil content of the sands outward to the eight "fringe" wells situated radially in each quarter-section.

Repressuring has been adopted recently in the Rhodes Pool, Jack County, Texas, as a means of increasing ultimate recovery from the reservoir[9]. Gas from 54 producing wells, after being stripped, is returned to the formations through 12 injection wells, 6 assigned to each of the two producing zones. Gas returned underground is compressed to 350 lb. per sq. in.

Gravel-Packing

An example of the general manner in which the oil industry is alert and quick to adopt methods and practices from other fields of industry that may be used to advantage is the adaptation of gravel-packing for use in oil wells in which sand troubles are aggravated. First introduced into oil-well practice several years ago, the last year has witnessed a wider acceptance of this method of combatting loosely consolidated sands.

Gravel-packing of oil wells has now progressed to a stage that its worth may be evaluated definitely in comparison with other more conventional methods of dealing with sand trouble in producing wells. A paper presented recently in California[10] includes an interesting analysis of production costs in wells comparably situated except for the method of preventing ingress of sand to the well bore. The following table is taken from the paper:

Operating Costs of Wells in the San Joaquin Valley, California

Group	No. of wells	Direct cost pumping and bailing, dollars	Direct cost pump repairs, dollars	Total cost, dollars	Total oil prod.	Bbl. per dollar	Cost per bbl., cents
West side group							
Conventional	5	4060.65	2081.13	6141.78	212,730	35	2.0
Gravel-pack	11	4931.05	2201.18	7132.23	613,087	86	1.2
East side group							
Conventional	8	1918.91	371.95	2290.86	83,803	37	2.7
Gravel-pack	5	936.48	272.83	1209.31	91,743	76	1.3
Northerly group							
Conventional	1	9.89.15	81.13	1070.28	10,519	10	10.0
Gravel-pack	4	1713.55	294.64	2008.19	60,852	30	3.3

During the last year, gravel-packing has been used extensively in the Gulf Coast and Mid-Continent areas as a solution to sand problems in certain fields. A newly-devised method, developed on the Gulf Coast in Texas, for gravel-packing through perforated casing points the way to the use of gravel-packing as a remedial measure in many old wells in which sand trouble is aggravated but in which the producing zone is accessible only through perforations[11].

Bottom-hole Choking

The use of bottom-hole chokes has increased during the last year. No outstanding new designs or developments in practice have appeared but the principles of bottom-hole choking are gaining wider acceptance and are better understood. In general, bottom-hole choking permits control of pressure and production in the well rather than at the surface. In nearly every well, control is necessary to some extent. Elimination of freezing caused by pres-

[5] "Laboratory Technique and Equipment for The Study of Condensate," by W. F. Fulton. Paper presented at Spring Meeting, Southwestern District, A.P.I., March 17, 1939.

[6] Data presented before the Texas Railroad Commission by Dr. F. V. L. Patten. For abstract of data, see "Phase Equilibria in High Pressure Condensate Wells," by F. V. L. Patten and Denny C. Ivey, *The Oil Weekly*, December 12, 1938.

[7] "Recycling Plant Improves Efficiency of Production in Stratton Field," by E. E. DeBack, *The Petroleum Engineer*, March, 1939.

[8] "Excess Gas is Returned to Sands in Salem and Loudon Fields," by H. Lee Flood, *The Petroleum Engineer*, March, 1939.

[9] "Residue Gas from Gasoline Plant is Returned to Two Producing Sands," by Jo H. Cable and Frank H. Love, *The Petroleum Engineer*, April, 1939.

[10] "Economics of Gravel-Packing in California," by William A. Clark. Paper presented at Spring Meeting, Pacific Coast District, A.P.I., Los Angeles, California, April 11, 1939.

[11] "Extrusion of Gravel Pack Through Perforated Casing," by H. Lee Flood, *The Petroleum Engineer*, April, 1939.

sure reduction at the surface is one outstanding advantage of bottom-hole choking that justifies its use. It is more logical to obtain the pressure reduction (and temperature drop) in the well-bore, surrounded by the higher temperatures prevailing there. Experience has proved that most of the temperature drop accompanying the pressure drop will be restored to the gas or fluid only a short distance above the choke because the heat of the formations serves to warm the gas or fluid.

One of the interesting results of the use of bottom-hole chokes has been the reduction in the amount of cutting, or emulsion formed, when bottom-hole chokes are used. It would be more accurate to say that whether the amount of emulsion formed is reduced or not, its character is at least different. Separation of the emulsion occurs sometimes in the tubing-string when bottom-hole chokes are used. The well produces alternate volumes of pipe-line oil and water. This beneficial effect of bottom-hole choking is possibly explained by the higher temperatures at which choking occurs and the sustained heating effect during the travel of the fluid upward through the tubing.

An innovation in bottom-choking practice is the side-door choke used to advantage in wells to utilize gas pressure of an overlying sand to lift oil from a sand in which there is very little gas pressure available. The side-door choke is made-up in a tubing-string so that it will set opposite the gas sand. A packer placed lower on the tubing is set to close the annular space between the tubing and the casing. Gas from the upper sand is admitted to the tubing through the side-door of the choke and is used to lift the oil from the lower formation. At least 40 of these chokes have been installed in wells in New Mexico during the last year. The device is adaptable for use in any well in which the oil zone is deficient in gas but in which there is an overlying gas sand. In other areas, the side-hole choke is being installed in older wells in which gas zones are known to be cased-off. The casing is perforated and the gas is made available for use in continuing production from the oil zone.

A further advance in bottom-hole choke design that may have a decided effect on production practice under certain conditions is promised in the very near future. In answer to the need for a variable bottom-hole choke that would be automatic in operation, this new design will be operated entirely by the pressure differential across the choke. The valve in the choke will be controlled by a spring calibrated to resist any desired amount of pressure. For example, assume a formation pressure of 2500 lb. per sq. in. The variable choke has a 2000-lb. spring. As long as the pressure on the upper side of the choke is 500 lb. or more, the valve in the choke will remain closed. If the pressure is reduced below 500 lb. by opening the well at the surface, the valve will open and remain open until the pressure increases again to 500 lb. If the withdrawal of gas at the surface continues or increases, the valve will open more, permitting a greater volume of gas to pass through the choke.

Gas-lift Methods Become More Automatic, More Efficient

Great progress in gas-lift is in evidence. The extensive studies and tests of the function of gas as a lifting medium for oil have resulted in important improvements in the design and operation of gas-lift projects.

In the East Texas field, high-pressure gas from condensate wells has been used to produce oil by gas-lift in wells requiring artificial means of production. Flow valves inserted in the tubing-string, having all the valve mechanism outside the tubing, have been adopted successfully in some of these wells.[13]

Production methods in the Rodessa field are also described in articles appearing recently.[14] Excessive gas-oil ratios during the early development of the field depleted the reservoir pressure rapidly. Some wells are still flowing but gas-lift and pumping installations are becoming more prevalent rapidly.

The very active Gulf Coast area extending from Victoria County, Texas, southwest to Kleberg County is presenting some interesting production problems.[15] Producing horizons in this area are principally loosely consolidated sands. This sand, if allowed to enter the well-bore, results in severe abrasive action on the well equipment. Small-gauge wire-wrapped screens have been used opposite the sand section. Recently, however, successful completions have been obtained by setting the casing on bottom, perforating, and producing without screen or liner. Prorated production and the accompanying lower rates of velocity have reduced the sand hazard considerably.

[13] "Gas-lift Project in East Texas Field Utilizes Gas from Distillate Well," by John W. Lee and Frank H. Love, *The Petroleum Engineer*, December, 1938.

[14] "Production Methods in the Rodessa Field," by T. H. Gibbs, *The Petroleum Engineer*, May and June, 1939.

[15] "Oil Development and Production Practice in Southwest Texas," by C. H. Row and R. H. McLemore. Paper presented at Spring Meeting, Southwestern District, A.P.I., March 17, 1939.

Production in West Texas (Ward County and other areas) has presented probably the worst sand condition that has been encountered in recent years. Infiltration of sand into the well-bore has been so serious that in many instances a well will sand-up again within 16 to 18 hours after it has been cleaned-out. Pumping has been abandoned almost entirely as a production method because of the difficulty of keeping the equipment free of sand and in service. Several methods of gas-lift have been tried with indifferent success. One of the companies operating in Ward County, however, has recently designed a device that shows promise of definitely solving the problem. The essential feature of this new-type gas-lift mechanism is a control-valve, made-up in the tubing-string at a depth selected to result in the desired volume of production per flow. The valve is designed so that it is entirely removed from contact with the sand-laden oil during all phases of the production cycle. The valve is actuated by a sinker-bar, operated from the surface by an automatic device controlled entirely by a timing device. Perhaps the most important single element in this new method is the inner macaroni-string that impinges the injected gas directly upon the standing valve at the lower end of the tubing. The velocity of this impingement agitates any sand that may be collected upon the valve so that it may be evacuated with the oil.

Progress in Pumping Methods

There was a time when the more enthusiastic advocates of gas-lift predicted that pumping methods would sometime be entirely supplanted. Developments of the last year have more than disproved any semblance of accuracy in such a statement. Pump design has been improved materially and pump performance is being subjected to a thorough study in several quarters.

Among other studies that have been reported during the last year, an analysis[16] of factors influencing the application of pumping units has shown that geared units should be selected on the basis of peak-torque requirements. Maximum well load, however, as a basis for calculating peak torque does not result in accurate performance at high speeds. Studies of individual wells have shown that at high speed, peak torque may be less than at moderate speed.

During the last year, pump-performance was subjected to a rather thor-

[16] "Factors Influencing the Application of Pumping Units," by Emory Kemler, *A.P.I. Drilling and Production Practice*, 1938.

ough study by a committee of the A.P.I. in California.[17] The results of the test indicated that properly proportioned pumping units will operate without serious loss of efficiency. If low efficiency is experienced, the cause probably will lie elsewhere.

The practice of using dynamometers to analyze well performance and other power problems is increasing. More companies are recognizing the value of thorough study of power losses. Dynamometer data have application during three phases of a well's history[18]:

(1) in selection of equipment by rating the well,

(2) in checking operation after the equipment is installed, and

(3) in correcting trouble when wells do not perform properly.

Dynamometers may be used to advantage in counterbalancing central powers.[18]

As the depth of wells pumped by central powers has increased, greater study has been given to the design and efficiency of the various pieces of equipment used in central pumping. These studies have included dynamometer tests of the pumping equipment and, in some instances, rather elaborate laboratory methods of analyzing stresses in the equipment parts. An example of the attention given to studies of the latter type is the use of celluloid models of notched hook-off bars subjected to photo-elastic analyses employing polarized light to detect the nature of the stresses within the models[19].

Production Services

Much of the progress in obtaining more efficient production methods has been possible only through the development of the "services" that are available to the driller and producer.

Cementing. The last year has witnessed further development of the cementing technique termed squeeze-cementing. It has proved of great value in correcting unsatisfactory original completions and as a means of selectively excluding fluids from the well, i.e., water control and gas control. Unsuccessful cementing in original well completions is usually attributable to one of the following factors[20]:

(1) The presence of clays or shales in the hole that will not form a strong bond with the cement, requiring more cement than was calculated.

(2) Mud contamination and weakening effect of magnesium sulphate in the underground waters.

(3) Crooked hole preventing centering of pipe in the well—results in unequal distribution of cement.

(4) Channelling due to irregular-shaped hole.

(5) Variable-weight and underweight slurry.

The need for special cements in deeper drilling has resulted in the development of new test methods and in an attendant confusion concerning comparability of results obtained using various test apparatus and methods. A committee of the A.P.I. has recently presented a report[21] in which test methods have been analyzed and evaluated. The need for standardization is stressed and it is proposed that a code be formulated governing test methods.

Acidizing. During the last year, acidizing has further proved its worth as sometimes the only means by which commercial production may be obtained from tight limestone formations.

An example of this valuable service is found in certain of the newly-developed producing areas in the Illinois Basin. One of the producing formations in this area is the McClosky limestone, an oölitic rock of varying porosity. In many instances, wells drilled into the McClosky have failed to show so much as a drop of oil until the formation has been given an acid treatment. In this way, many wells, otherwise "dry", have been converted into commercial producers.

Gas-well acidizing, developed during five years of application in various fields of the Mid-Continent area and elsewhere, has been accepted generally as a standard production practice in limestone areas[22]. An analysis of acidizing results in 47 wells in the Panhandle disclosed an average increase of 135 percent in open flow at a cost of $77 per million cu. ft. of increase obtained.

Developments of General Interest

Considerable study has been devoted during the last year to an evaluation of different producing methods. Data are being collected under the auspices of the American Petroleum Institute by various members in assembling a report that should, when completed, represent a valuable contribution to the industry as an aid to selecting more accurately the correct producing method to be used.

Water-flooding. Water-flooding is now accepted in the Mid-Continent fields as a valuable secondary recovery production method. Many old properties, no longer economical when produced by pumping methods alone, may be produced by a water-flood if certain elements are favorable. An analysis[23] of the factors that should be considered in evaluating properties for water-flooding outlines a representative evaluation of a 160-acre project in the Mid-Continent. It is estimated that $400 per acre could be paid for the property if oil could be sold for $1 per bbl. and if 10 percent is charged as the interest—6 percent on the investment and 4 percent to cover the risk.

Production from horizontal wells. The drilling of the first horizontal well near Marietta, Ohio, has attracted widespread interest in the industry[24]. Of greater interest than the mere novelty of drilling horizontally is the possibility that oil sands may be exploited in the future by horizontal wells to increase materially the sand area exposed.

Segregated production. Methods have been developed for segregating production from various zones in the same well. Segregation of production is desirable when formation pressures of the different zones differ materially. Other characteristics of the individual formations may make it desirable to produce from them separately. In the Long Beach Harbor district of the Wilmington field, California, segregated production is obtained from three sands —the Ranger, Upper Terminal, and Lower Terminal. Well equipment and methods have been described in an earlier issue [25].

Segregated production has proved desirable in the Loudon area, Illinois. In that field, alloy sections are inserted in the casing opposite the upper producing zone. Later, if it proves desirable, these alloy sections may be drilled-out or dissolved by acid to obtain production from both producing formations, separately or together as desired.

---

[17] "Report on A.P.I. Pump-performance Experiment" by M. G. Arthur and E. K. Parks, *A.P.I. Drilling and Production Practice*, 1938.

[18] "Typical Dynamometer Cards and Their Application," by Eugene Hosford and Emory Kemler. Paper presented at Midyear Meeting, A.P.I., New Orleans, Louisiana, May 18, 1939.

[19] "Analysis of Stresses in Hook-offs for Wells Pumped by Central Powers," by Kenneth N. Mills, *The Petroleum Engineer*, October, 1938.

[20] "Selective Exclusion of Fluids from Wells," by Paul D. Torrey. Paper presented at Midyear Meeting, A.P.I., New Orleans, Louisiana, May 18, 1939.

[21] "Cement for Oil Wells: Status of Testing Methods and Summary of Properties." Paper presented by W. W. Robinson at Midyear Meeting, A.P.I., New Orleans, Louisiana, May 17, 1939.

[22] "Gas Loading, Stage Treatment, and Chemical Plugs Have Improved Gas Well Acidizing," by O. W. Lyons, *The Oil Weekly*, September 12, 1938.

[23] "Evaluation of Mid-Continent Properties for Water-Floods," by L. M. Arnold, *The Oil Weekly*, October 3, 1938.

[24] "The First Horizontal Oil Well," by Leo Ranney, *The Petroleum Engineer*, June, 1939.

[25] "Well Equipment and Completion Methods Used to Segregate Oils Produced from Different Zones at Wilmington," by Wallace A. Sawdon, *The Petroleum Engineer*, August, 1938.

Progressive Trends in Gas-Lift Operations

By S. F. SHAW, Consulting Engineer

PROGRESS in gas-lift operations during the last year has proceeded along different lines from those that prevailed during previous years. The trend has been toward the use of gas-lift for producing small wells for the purpose of reducing installation costs for equipment, and for reducing operating costs to a minimum. The severe restriction in production that has been enforced in various recently-discovered fields in Texas has been largely responsible for this trend. The use of gas-lift for producing large volumes of fluid containing high percentages of water has continued in some fields, and operators have observed that wells producing large quantities of fluid, that is, from 2,000 to 20,000 bbl. per well per day with only one-half to three percent oil, allows a margin of profit to be made, provided conditions associated with the lifting of these large quantities are sufficiently favorable.

Methods of gas-lift in use at the present time consist principally of the following:

1. Straight, or continuous gas-lift, employed in Kettleman Hills field, California; Rodessa field, Louisiana; Oklahoma City field, Oklahoma, and Corpus Christi, Hendrick, Placedo, Refugio, and Saxet fields, Texas.

2. Gas-lift centrifugal-pump combination method employed in Oklahoma City field, Oklahoma.

3. Intermittent flow method employed in Rodessa, Benavides, Lopez, Means, Saxet, South Ward, and various pools in West Texas.

4. Plunger-lift method used in Coyote, Del Rey, Dominguez, Huntington Beach, Kettleman Hills, Mountain View, Santa Fe Springs, Seal Beach, Shiell's Canyon, and Ventura Avenue fields, California; Rodessa field, Louisiana and Texas, and Lucien, Moore, and Oklahoma City fields, Oklahoma.

Straight or Continuous Gas-lift Method

A few wells in the Simpson zone in the Oklahoma City field are still operating on straight gas-lift. One well is producing approximately 1200 bbl. of fluid per day of which 450 bbl. is oil. The input-gas factor is 4250 cu. ft. per bbl. of fluid, and the output-gas factor is 4920 cu. ft. per bbl. Data on a few wells operated on straight gas-lift in this field are as follows:

S. F. SHAW

received a degree in mining engineering from Columbia University in 1903—From that time until 1926 he was with various mining organizations in Mexico and Costa Rica—While with the American Smelting and Refining Company in Mexico a part of his work involved dewatering of mines by the application of air-lift—This experience and knowledge he later applied to the lifting of oil by air-gas lift methods—Since 1926, during which time he has been connected with various oil companies and has operated as a consulting engineer, he has constantly studied and applied air-gas lift principles to oil production and is considered an authority on the subject—His home is in San Antonio, Texas.

The wells for which data are given in the above table are producing from sand at a depth of about 6500 ft. Casings are 7-in., 8⅝-in., or 9⅝-in. O.D., and tubing diameters are 2½-in. and 3-in. In some cases the input factors seem high, but when the flowing pressures are considered it appears that the lifting efficiency is fairly good.

Gas was compressed in one plant at an average operating cost during 1938 of 0.88 cent per M cu. ft., and in another plant the cost averaged 0.97 cent per M cu. ft., not including amortization charges. Down-time on the gas-lift wells served by these plants is very slight compared with that on the offset wells in which conventional lifting methods are employed.

In the Hendrick pool, Winkler County, Texas, wells are producing as much as 21,000 bbl. of fluid per day and oil percentages in some cases are less than one percent. When gas can be obtained at a cost of approximately 2 cents per M cu. ft., lifting costs in wells not requiring a high input factor are said to range from 0.5 to 0.016 cent per bbl. of fluid, or from 2 to 7 cents per bbl. of oil. Input factors are reported to average about 40 cu. ft. per bbl. of fluid.[1] In this field, 78 wells were producing on gas-lift during October, 1938, and most of these wells were produced by using continuous gas-lift methods.

In the Corpus Christi field, Texas, input ratios range from 440 to 1340 cu. ft. per bbl. of fluid, depending largely on the quantity of fluid that can be lifted per day. The wells in this field are completed using 5½-in., 6⅝-in., or 7-in. casing. Wells in which 7-

[1] "Gas-lift now being more widely adopted throughout many West Texas fields," by D. H. Stormont, *The Oil and Gas Journal*, May 4, 1939.

Data on Wells Operating on Straight Gas-lift in the Oklahoma City Field, Oklahoma

Well	Bbl. fluid per day	Percent water	Cu. ft. input gas per day	Cu. ft. input gas per bbl.	Cu. ft. output gas per day	Cu. ft. output gas per bbl.	Pressures, lb. per sq. in. working	Pressures, lb. per sq. in. flowing
A	1200	62.5	5,100,000	4,250	5,900,000	4,920	480	390
B	500	85.0	1,100,000	2,200	.....	.....	400	.....
C*	75	58.7	1,879,000	25,050	2,449,000	32,650	300	39
D*	420	85.0	1,970,000	4,690	2,425,000	5,770	385	96

*Wells C and D are flowing on a schedule of one hour on and one hour off.

in. casing is used permit nearly twice as much fluid to be produced per day as those having 5½-in. casing; input gas factors, and operating costs, therefore, are reduced to nearly half.

When large quantities of fluid must be produced by the operator to obtain the daily allowable of oil, the operator is learning that large casings are sometimes the redeeming feature of the entire operation, both from the viewpoint of daily yield and of operating costs per bbl. of oil.

A noteworthy feature in connection with the flowing wells in the Corpus Christi field is the low cost of gas. The gas used for input purposes is sold at a rate of $150 to $300 per month per well supplied, an equivalent cost of approximately 0.5 to 1 cent per M cu. ft. The large quantity of water produced must be disposed of at a low cost, however, or it becomes impossible to operate such wells at a profit. The salt water produced in wells near the Gulf Coast can be piped to the bays in the immediate vicinity at very low expense. In other places, salt-water disposal wells have been drilled as a means of disposing of a large quantity of water.

Continuous gas-lift is employed in the Placedo field, Texas, on wells producing from the Greta sand. These wells have a fairly high reservoir pressure, and yet in these wells the producing formation is tight, that is, it has low permeability and will yield only a comparatively small quantity of fluid per day. In such cases, no attempt is made to reduce the flowing pressure at the bottom of the well to a low value, as very little increase in production results. The fluid level is allowed to remain at a fairly high point, thus permitting the fluid to be lifted with comparatively low input-gas ratios.

The use of gas-lift in East Texas has been steadily increasing. In February, 1939, some 675 wells were being produced by this method, and another 661 wells had been similarly equipped. In the latter, however, it has not yet been necessary to employ gas-lift.[2]

Gas is supplied to the wells in the East Texas field from the following sources:

1. Gasoline plants discharging residue gas at high-pressure—297 wells.

2. Booster plants, using residue gas from gasoline plants—219 wells.

3. Recycle plants on the lease—93 wells.

4. Air-lift compressor plants on the lease—17 wells.

5. Directly from high-pressure gas wells—49 wells.

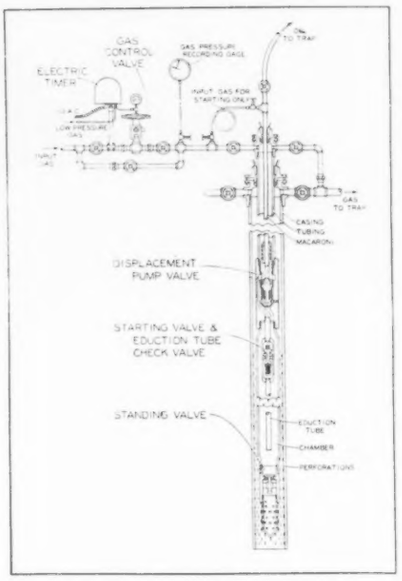
The least expensive method of starting wells on gas-lift in the East Texas field is to employ high-pressure residue gas direct from a gasoline plant where such gas is available, or to use gas obtained from a gas well. In either of these cases, the only expenditure for equipment necessary is for field lines, regulators, and other control equipment. When a compressor plant is to be installed on a lease, a unit capable of supplying 10 to 20 wells can be installed for approximately $8500, an equivalent cost of about $850 to $425 per well for the plant equipment. A plant was constructed in 1938 by the Ellis Oil Company, containing one 225-hp. angle-type compressor to take gas from 27 wells on two leases, on which 12 wells had been previously produced by conventional sucker-rod pumps. The total equipment is reported to have averaged $1500 per well[3]. It is anticipated that the addition of another 225-hp. compressor installed when needed later will provide sufficient capacity to produce the wells until the sand is depleted. The additional unit will increase the average cost of equipment to a total of $2250 per well, it is estimated.

Combination Gas-lift Centrifugal-pump Method

The combination gas-lift centrifugal-pump method is being employed in a few wells in the Oklahoma City field for lifting oil when large quantities are still obtainable. Data on the operation of some of these wells are as follows:

Cost of Gas

Well	Bbl. per day	Cu. ft. input gas		Cost of gas, cents per bbl.	Power consumption, kw-hr.		Cost of power, cents per bbl.
		per day	per bbl.		per day	per bbl.	
A	1700	3,320,000	1953	2.2	2050	1.20	1.69
B	1665	2,490,000	1495	2.5	1395	0.84	1.21
C	1970	3,480,000	1766	3.0	1560	0.79	1.09
D	1860	3,750,000	2016	3.0	1780	0.96	1.33



Representative installation of one type of gas-displacement pump

Intermittent-Flow Gas-Lift Method

Intermittent flow of certain types is becoming more popular for lifting oil from wells having low allowables, in which input gas factors must be maintained at a minimum in order to obtain a low operating cost.

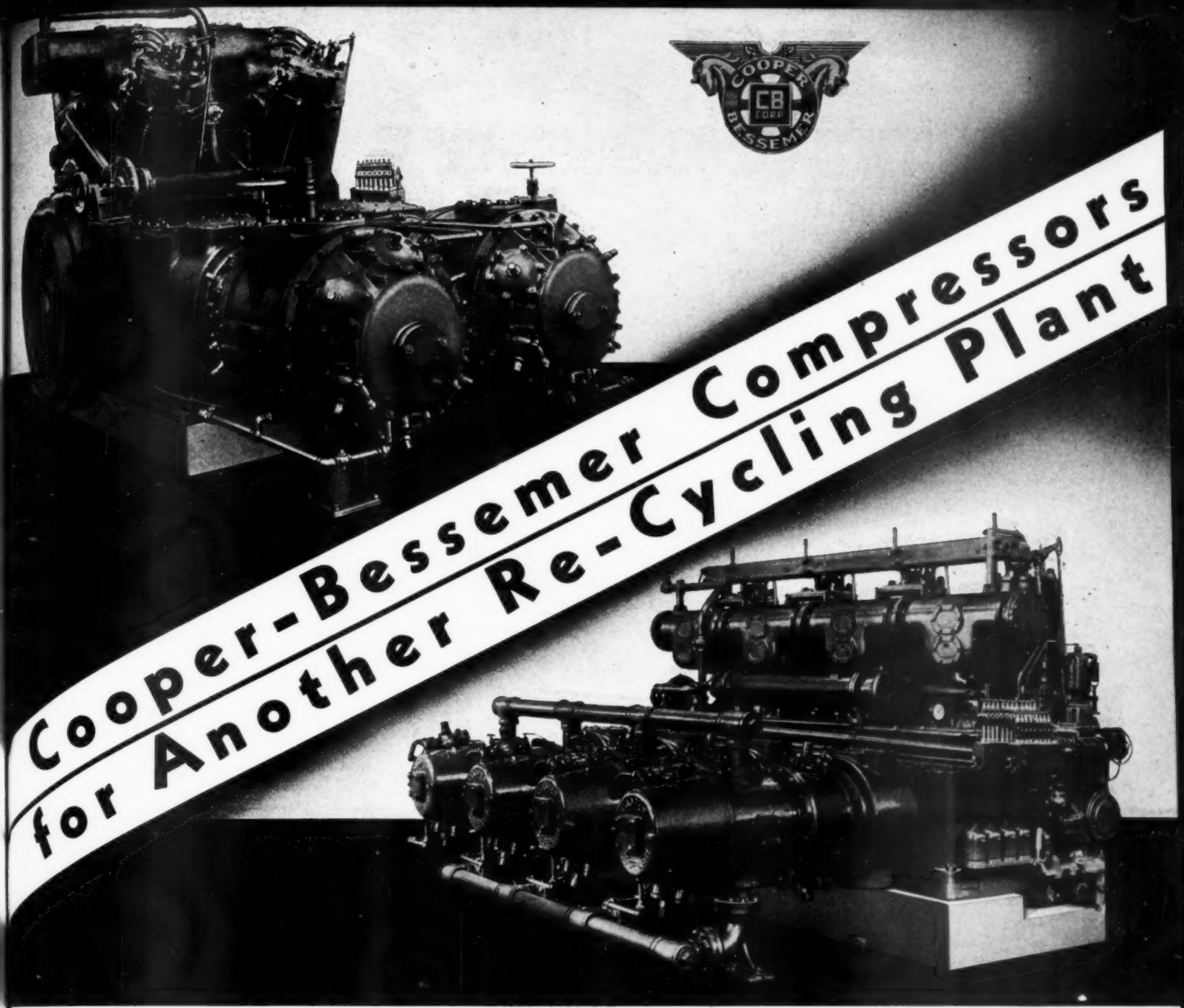
In some fields in which the wells have high fluid levels but will not flow naturally, successful results have been obtained by running a small string of tubing, 1-in. or even smaller, inside the regular tubing string, and providing for gas injection through the inner string to flow the oil through the annular space. When 2-in. tubing is employed as the regular string, the annular space is so restricted that only a small quantity of fluid can be lifted daily. When 2½-in. or 3-in. tubing is employed, fairly satisfactory results may be obtained until the fluid levels decline to a low point.

In one intermittent control method, the inner string is provided with valves spaced at intervals of a few hundred ft., of a type that may be manipulated from the surface. By turning the inner tubing string any desired valve may be opened to admit the gas from the inner tubing at this point and flow the oil through the annular space. The valve may also be closed by turning the smaller tubing string. In another type, kick-off valves are inserted in the inner string at suitable intervals. These valves operate automatically in admitting gas to the annular space.

Another surface-control gas-lift device may be employed either as a continuous method, or as an intermitting

[2] "Gas-lift in East Texas," by W. N. Rees, *The Oil and Gas Journal*, February 16, 1939.

[3] "Gas-lift Plant Has Several Features," by R. C. Smart, *The Oil Weekly*, September 19, 1938.



Tidewater Associated and Seaboard Oil companies have chosen G-MV and G-MR compressor units for their new re-cycling plant at Long Lake, Texas. Built for these partners-in-development, by J. F. Pritchard and under Vaughn Process plans, this new plant marks another forward step in modern refinery practice.

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method for flowing through the tubing. Side-opening valves are inserted in the tubing at suitable intervals, and are operated by a sinker-bar that is lowered on a wire line from the surface to actuate and open the valve situated at the point at which it is desired to admit the gas. Gas from the casing then enters the tubing string and lifts the fluid through the tubing to the surface. In the continuous method, the sinker-bar is held at this point after kicking-off the well, to maintain the valve in an open position and permit all the production to come from this depth. In the intermittent method a pneumatic cylinder is suspended above the tubinghead, and the wire line supporting the sinker-bar is attached to the lower end of a piston, inside the cylinder, the movement of which is actuated by gas. Admission of gas into the cylinder to raise the sinker-bar is controlled by a time-cycle intermitter on the surface. Cut-off of gas to permit the piston (and sinker-bar) to lower at the close of the flow is controlled by the change in flow at the tubinghead as the flow of liquid diminishes and gas begins to blow through. Fields in which this method is employed include Barbers Hill, Benavides, East Texas, Lopez, Means, and South Ward, all in Texas.

The usual method of intermitting, in which a chamber at the bottom of the well is employed, consists of displacing the fluid through the tubing, but when a considerable volume of fluid must be displaced during each cycle, the method has been altered so that the fluid is displaced into and through the casing above a packer. In this latter method, a chamber of suitable length is attached to the lower end of a string of tubing, and a packer is set above the chamber. Perforations above the packer allow the fluid to be displaced from the chamber into the casing, and the gas that is carried through the tubing to the bottom of the chamber displaces the fluid from the chamber into the casing and then lifts it to the surface. Inasmuch as the casing area is greater than the tubing area, the quantity of gas employed per cycle is greater than when using the tubing for this purpose. On the other hand, lower pressures can be employed when lifting considerable volumes of fluid. This method was quite popular in the Oklahoma City field at one time for intermitting through casings of 6⅝ in. and 7 in., to lift as much as 1000 bbl. per day. Several of these installations are now employed in the Rodessa field.[4] A few installations have been made in the Turner Valley field, Canada, in an effort to reduce gas-oil ratios, rather than to employ the method solely for artificial lifting of the oil.

One intermitting method has been employed for more than ten years in various fields of California, and in the Mid-Continent, Trinidad, and other areas. Improvements have been made on this system and installations are in operation in the Dominguez, Santa Fe Springs, and Kettleman Hills fields, California.

Plunger-lift Method

The plunger-lift is being employed in various fields—about 50 units are operating in the Rodessa field, in Louisiana and Texas, 35 units are operating in California, and 73 units have been shipped to foreign countries.

Data on wells operating on plunger-lift in various fields are given in the following table:

Data on Plunger-lift Operations in Various Fields

Field	Tubing diam., in.	Depth of foot piece, ft.	Bbl. per day			Pressure on casing, lb.	Cu. ft. input gas	
			fluid	oil	water		per day	per bbl.
Oklahoma City	4	6437	165	160	5	75	.....	.....
Kettleman Hills	4	7803	408	402	6	260	802,000	1966
Kettleman Hills	4	8200	230	89	141	265	880,000	3826
Shiell's Canyon	3	3797	156	131	25	155	.....	.....
Coyote	3	4055	227	226	1	99	80,000	352
Dominguez	3	5026	141	34	107	165	519,000	3681
Del Rey	3	6307	145	135	10	95	.....	.....
Santa Fe Springs	3	6800	135	134	1	160	452,000	3348
Rodessa	3	6000	136	136	0	100	68,200	501
Lucien	2½	5125	18	18	0	48	117,700	6539
Seal Beach	2½	5640	88	84	4	80	.....	.....
Rodessa	2½	6000	154	154	0	185	430,700	2797
Rodessa	2½	6000	81	40	41	108	383,300	4732
Rodessa	2½	6000	24	24	0	50	91,200	3800
Oklahoma City	2½	6527	42	26	16	85	.....	.....
Ventura Avenue	2½	6878	92	88	4	134	.....	.....

In October, 1938, there were 141 wells on gas-lift in West Texas, and another 173 wells were equipped with kick-off valves of one make or another. Early in 1939 there were 265 wells on gas-lift, and 225 wells were provided with starting valves, thus indicating the increase being made in the number of wells equipped to lift fluid by this means.

Starting valves, or kick-off valves, are being employed to good advantage in wells in which the fluid level is high, but the flow into the well is not great owing to the tight character of the producing formation. When this type of well is closed-in, the fluid level rises to a high point, and it is desirable to kick-off these wells with a pressure that is not excessive. For this purpose kick-off valves are particularly adapted. Kick-off valves either are positively controlled by being opened from the surface or are automatic.

Stormont[1] states that natural gas under sufficiently high pressure is being employed for gas-lifting wells in the Means field, Andrews County, Texas. In this field there are 25 wells producing on continuous gas-lift and 20 wells employing kick-off valves to regulate the flow. In the South Ward field, surface-controlled gas-lift equipment is being employed in some of the wells. There are 67 wells in the South Ward field and 26 wells in the North Ward field being produced on some form of gas-lift at the present time.

Starting valves are used to a considerable extent in the Rodessa field because artificial lifting methods are rapidly becoming necessary.[4] Various types of valves are employed for starting the wells, after which the wells are flowed continuously; in some wells, however, the valves are used only as intermitters. Gas-lift in its various forms is being used much more extensively in the Rodessa field than any other type of artificial lifting method.

Studies of gas-lift methods during the last year have been predominantly of those methods in which the equipment has been employed for handling small daily allowables, and in which the use of flow valves and of the various types of intermitting equipment has largely excluded other types of gas-lift methods. An instructive paper was delivered by Cromer and Huntington before the A.I.M.E. meeting in San Antonio in October, 1938, describing motion studies of straight gas-lift as developed by experiments made at the University of Oklahoma. These studies were made employing 2-in. tubing having glass sections inserted in the eductor at various intervals. Both still- and motion-pictures were taken of the gas flow at points of no fluid flow, maximum efficiency, maximum capacity, and of no fluid flow owing to excessive use of gas, and it was observed that the type of flow changed considerably when passing through these various points.

[4] "Production Methods in the Rodessa Field," by T. H. Gibbs, *The Petroleum Engineer*, May, 1939.

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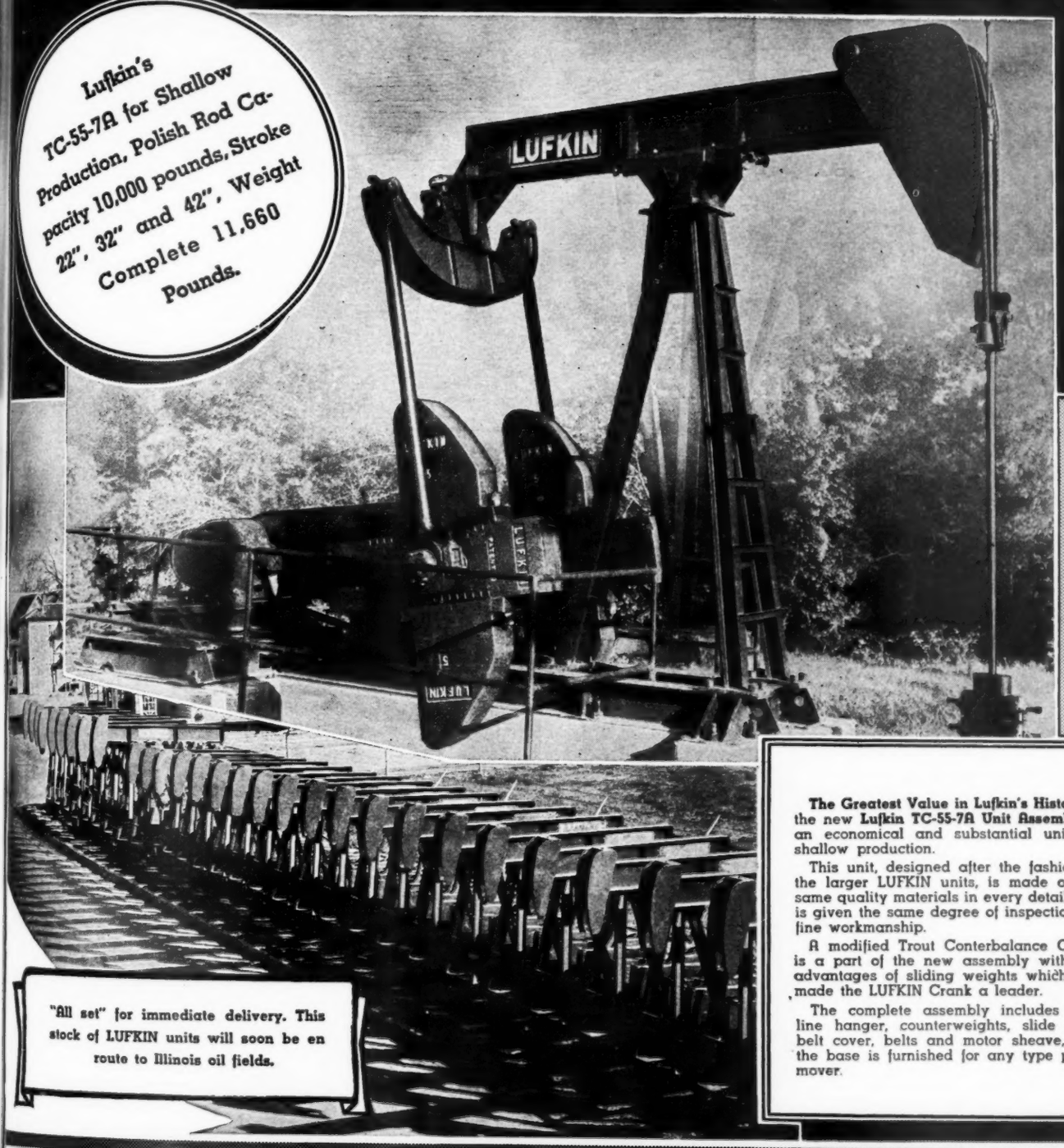

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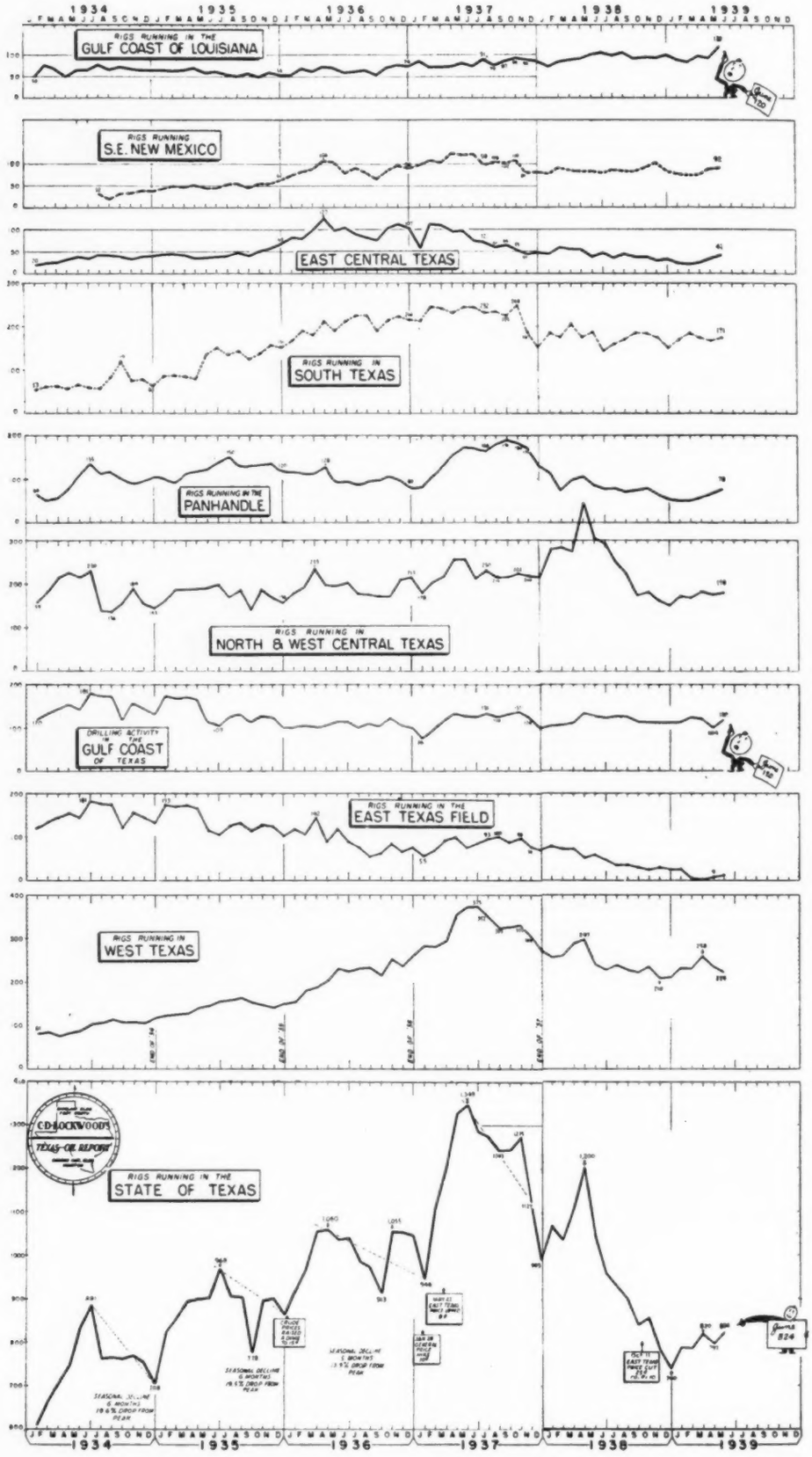
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RIGS RUNNING IN THE GULF COAST OF LOUISIANA
RIGS RUNNING S.E. NEW MEXICO
EAST CENTRAL TEXAS
RIGS RUNNING IN SOUTH TEXAS
RIGS RUNNING IN THE PANHANDLE
RIGS RUNNING IN NORTH & WEST CENTRAL TEXAS
DRILLING ACTIVITY IN THE GULF COAST OF TEXAS
RIGS RUNNING IN THE EAST TEXAS FIELD
RIGS RUNNING IN WEST TEXAS
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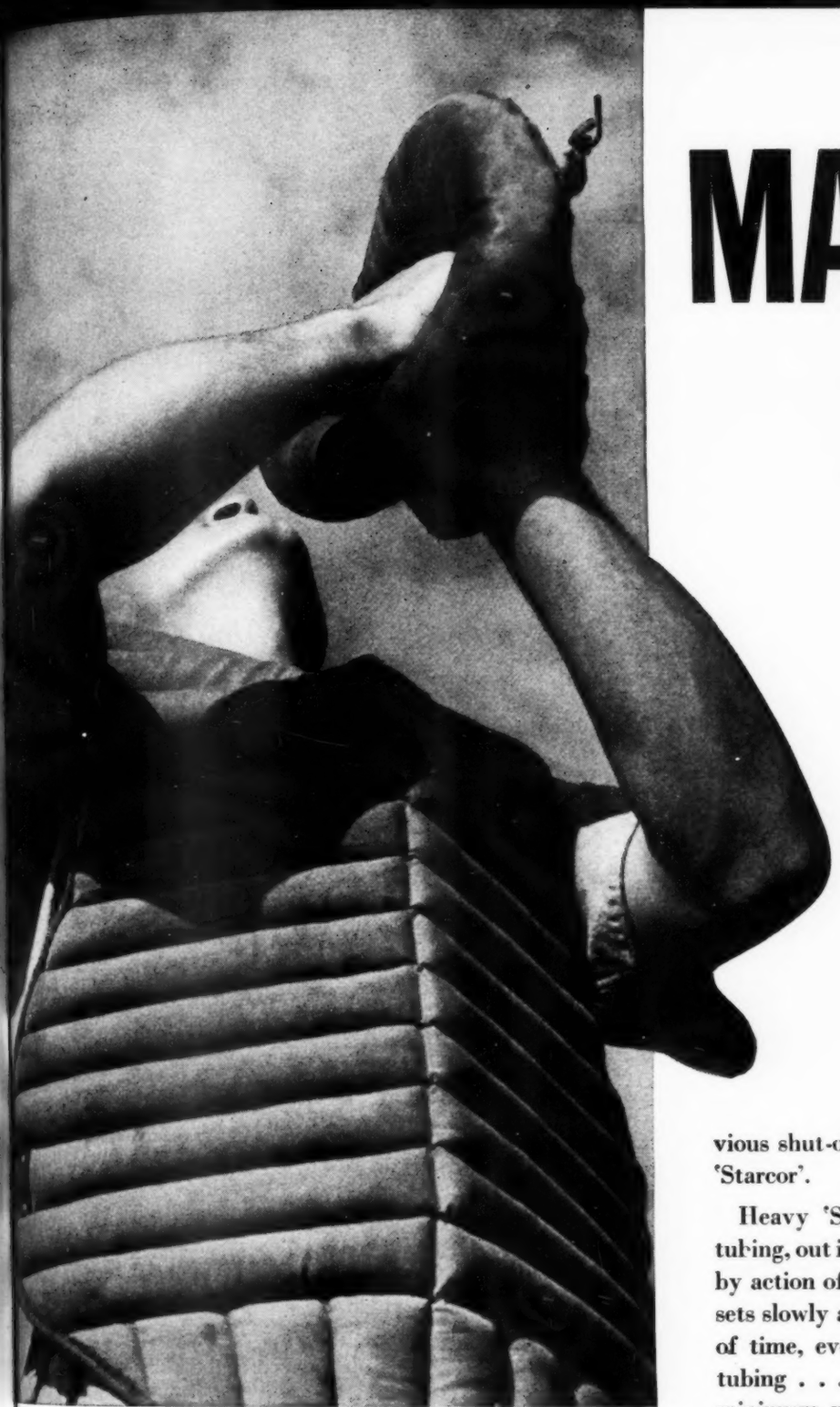
RIGS RUNNING IN THE STATE OF TEXAS

—Courtesy C. D. Lockwood's Texas Oil Report

Rigs running in Texas, Coastal Louisiana, and Southeastern New Mexico and comparisons with last five years



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Developments in Gravel-Packing

By WILLIAM A. CLARK

Division Petroleum Engineer, The Texas Company (California)

IT has become of importance to the operator during the present-day necessity of severe curtailment of production and a consequent reduction of current income, to take advantage of every aid that will tend to decrease operating costs.

John R. Suman of the Humble Oil and Refining Company in presenting a paper[1] before the A. I. M. E. in 1925 made the statement . . . "production costs are directly proportional to the amount of sand produced from the well, . . . "

The procedure known as gravel-packing has proved in most instances to be a remedy for operating difficulties caused by sand entering a producing well. Its use has resulted in a substantial reduction of operating costs in areas of loose or running sands. It is significant that today in California, in the short period of a little more than two years, there are in excess of 8000 bbl. of oil produced daily under proration from 78 gravel-packed wells in 13 oil fields.

Surrounding a screen or perforated liner with a sheath of gravel has been frequently discussed in the past as a possible method of completing an oil well. The procedure has been used in water wells for many years. The methods as developed, however, were not completely applicable to oil wells. A water well is often packed its entire depth from top to bottom, whereas in an oil well the zone must first be isolated by a primary casing string to shut-off top water. Also, many other theoretical and practical differences exist. It was not until 1937 that the procedure was successfully applied to an oil well.

It may be of interest to mention some of the theoretical and practical problems that had to be solved before gravel-packing of oil wells could be established on an engineering, rather than a hit-or-miss, basis.

Theoretical study and laboratory research have established the following:

(a) Ratios of sand-to gravel-sizes required to form stable bridges and prevent transportation of sand through gravel at different rates of fluid flow. Thickness of packs required for screening.

(b) Theoretical advantage of using large diameter drill holes for oil wells to increase ultimate and current production. Theoretical and test data comparing such open holes with holes filled with gravels and sands of different sizes.

(c) Choice of drilling fluids and of fluids for placing the gravel. Behavior of different types of mud within the gravel pack. Means of minimizing the danger of plugging the packs with mud cake.

Mechanical problems that had to be solved included:

(a) Methods of preparing the hole for packing. Selection of hole size.

(b) Design of the liner, means of centering it in the hole, and determination of perforation size.

(c) Means of insuring that the gravel reaches the bottom of the hole; means of determining when the gravel cavity is full.

(d) Means of minimizing the danger of sticking tubing or drill pipe by gravel.

(e) Methods and apparatus for introducing the gravel safely and economically.

It is evident that completions of wells by the gravel-packing methods are inherently somewhat more expensive than conventional completions. This fact has demanded a close economic study of actual performance of gravel-packed wells. New methods have been devised to reduce substantially the cost of gravel-packing until it now approaches that of a conventional completion.

Practically all gravel-packing in California has been done for the purpose of excluding sand. It has been economically justified on the basis of reduced operating cost.

When the first gravel-packed wells were completed there was no information available on the fundamental physical factors involved in the bridging and transportation of sand grains. The first gravels used, ½-in. to ¾-in. diameter, were too large to screen the sand completely but were still definitely beneficial to the wells in which production and hence, fluid velocities, were low.

Later, the well-known rule for bridging of slots by sand grains was adopted for gravel-packs by considering the effective diameter of the interspace between gravel as a slot. The controlling sand-grain size was assumed to be that at the 10 percent point on the cumulative grading curve. The following relationship was developed:

$$D_s = \frac{.155\ D_g}{2} = .0775\ D_g$$

$$= \frac{D_g}{12.9'}, \text{ or } D_g = 12.9 \times D_s$$

in which

D_s = effective sand-grain size (grain size at ten percentile)

D_g = required diameter of gravel grains for effective bridging of sand.

$.155\ D_g$ = relationship between sphere diameter and diameter of interstice of packing spheres.

Application of this rule to the selection of gravel in the field has resulted in a minimum of sand production. The accuracy of the rule has been confirmed in general in the laboratory; however, extremely high velocities of flow (probably never reached in most wells) cause the sand bridge to break down unless smaller gravels are used. At a ratio of six times the effective grain size there is no transportation of sand through the gravel at any velocity; furthermore, it was found in the laboratory that the small-size gravel had no detrimental effect on production rates as compared with those obtained through larger-sized material. The practicability, however, of the use of gravel finer than ten or twelve times the effective grain size in fine sands is questioned because of the difficulty in removing adherent mud from the gravel as well as removing mud cake from the sides of the hole.

Mechanical Developments

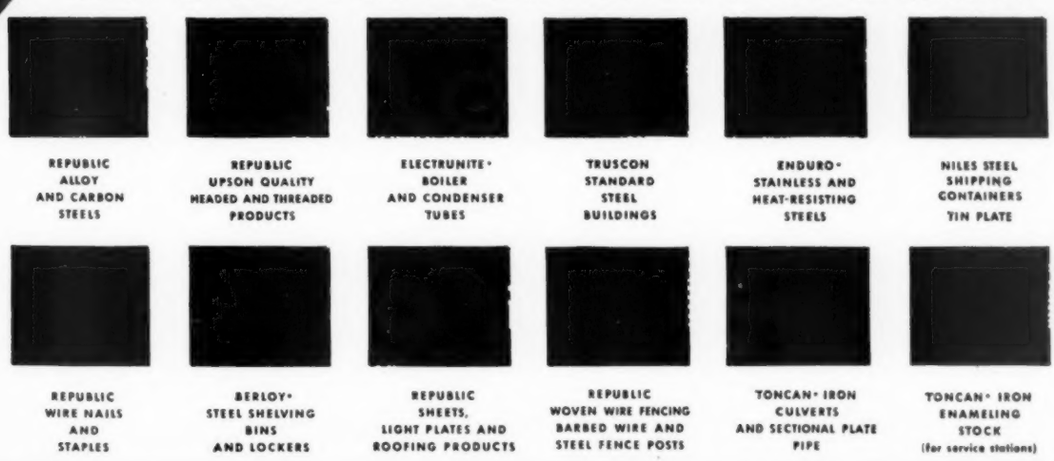
The diameter to which the hole through the oil zone is reamed has been left largely to the discretion of the operator. Undercutting tools may be obtained that will ream a 36-in. hole below 11¾-in. casing; however, since the stress has come to be placed on sand screening by the pack rather than on the increased production to be gained by a large hole, the tendency has been to reduce the size of hole dug.

The first holes were reamed to a di-

(Continued on Page 40)

[1] "The Sanding of Oil Wells," by John R. Suman, A.I.M.E. *Petroleum Development and Technology*, 1925, pp. 196-198.

OTHER REPUBLIC STEEL PRODUCTS FOR USE IN THE OIL COUNTRY



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(Continued from Page 36)

ameter of 20 in., providing an annular thickness of 6½ to 8 in. depending upon whether a 6⅝- or 5-in. liner was used. At the present time 11- to 15-in. holes are considered adequate for screening, as it has been demonstrated that a 2-in. thickness of gravel is sufficient. Difficulties, however, in exactly centering the liners, especially in thick oil zones, have led to the general practice of using about 5 in. The resulting reduction in cost of underreaming has effected a substantial saving, amounting in some cases to more than $5000 per well, besides reducing danger of twist-offs and fishing for small pipe in a large hole.

Of the various methods evolved for placing the gravel and liner within the well, the method of reverse circulation has become the most common. In this method, a liner containing a suitable conduit formed by blanking the perforations with cement, or by means of a wash pipe, is hung at the bottom of the hole. Formerly, gravel was alternately fed or pumped into the annular space between the casing and the suspending string, and washed down by reverse circulation. This means of introducing gravel has now been discarded largely in favor of pressure mixing machines, such as the Layne Graveler, in which the gravel is mixed directly with the circulating fluid and pumped continuously into the well.

Other methods have been tried during the development of the procedure. One was to fill the open hole with gravel and produce the well without a liner; another was to wash, jet, or otherwise force perforated casing through gravel previously dumped into the open hole; a third was to run gravel and liner together to the bottom of the hole; a fourth method was to pump the gravel by direct circulation through tubing run alongside the liner, which had been previously landed on bottom. Of the various methods, the last one mentioned shows promise of supplanting the method of reversed circulation, particularly in holes believed to contain large cavities or in wells drilled into low-pressure zones and where return circulation has failed. The method, however, requires a larger-diameter primary casing-string in order to allow passage of the tubing between the casing and the liner.

The liners used in gravel-packing have all been of the slot-perforated type, some being undercut and some straight slots. The slots are as large as can be used and still exclude gravel. The purpose of this has been to facilitate the removal of mud from the gravel-pack and admit any sand that may have entered the pack into the casing to avoid clogging the pack. Recently chemical methods have come into use to clean the pack more completely than is possible by purely mechanical methods.

The success achieved in many gravel-packing jobs is often directly traceable to the amount of planning done before the well was drilled. Planning will also result in considerable cost saving. The well should be planned from the bottom up, by selecting the minimum diameter of liner required for the anticipated producing condition, which will, in turn, depend on expected viscosity of oil and the volumes of oil and gas to be produced.

The primary string must be large enough to provide an annular clearance between it and the liner of at least one in. to minimize the danger of gravel bridging between them or on top of the liner while being pumped-in. This amount of space is sufficient for gravels up to ⅜-in. diameter; for smaller gravel the clearance may be reduced slightly.

A recent development has been the use of one or two joints of larger casing run on the bottom of the primary string to provide annular clearance around the liner. This necessitates running a blank joint after packing is completed to attach to the top of the liner and pack-off to the primary string above the enlarged shoe joint. This method has resulted in a considerable cost saving, as it permits the use of smaller primary casing.

Another variation has been the use of pre-gravel-packed liners. These are of two types; one consists of a double string of perforated pipe having the annular space filled with gravel; another is a perforated pipe enclosed in an annular sheath of gravel held in place by coarse wire screen. These necessitate an annular clearance outside the interior liner of 1½ to 2 in. and hence, require a larger primary casing for a given liner size. They do not serve exactly the same purpose as a regular gravel-pack but appear successful in excluding sand.

Economics of Gravel-Packing

As a result of study and experience most of the more pressing problems have been solved satisfactorily, although progress will undoubtedly continue and new methods be discovered.

From cost and performance data it has been established that a well-designed and properly-placed gravel-pack will:

(a) eliminate sand production and sand fills, thus reducing loss of current production resulting from loss of productive capacity and down-time;

(b) decrease operating cost, wear on pumps and equipment, well labor and expense of sand disposal;

(c) prevent the forming of cavities from the walls of which bodies of formation may slough off, impeding production or collapsing liners.

For instance, a group of gravel-packed wells at Maricopa, Kern County, California, shows a saving of $.017 a barrel on pulling, bailing, and pump replacement costs as compared with similar wells conventionally completed. At Wilmington a gravel-packed

TABLE I
Recapitulation of Data on Wells in Section 32-32-24

Well No.	TOTAL Down-time, hr.	TOTAL Prod. loss, bbl.	Elapsed time, mo.	AVERAGE Down-time hr./mo.	AVERAGE Prod. loss bbl./mo.	Ratio††, prod. loss to potential
Conventional wells						
15	1500	16,700	18	83	925	1.64
16	380	7,000	19	20	370	.31
18	360	7,100	15	24	475	.58
19	495	6,800	14	35	485	.72
Gravel-packed wells						
20	400	3,200	12	33	267	.53
21	96	1,000	12	8	83	.15
22	24	680	11	2	62	.09
23	250	3,800	10½	24	362	1.14
*24	30	420	9½	3	44	.07
*26	45	820	8	6	102	.21
*27	26	290	8	3	36	.12
*28	420†	800	7	60	114	1.06
*29	25	130	7	3	20	.13
Average for "A"				40	564	.81
Average for "B"				17	121	.39

*Gravel size based on sand grading.
†Attempting to obtain production through small mesh perforations and reperforating and washing with chemical.
††This column was included because producion loss will vary according to the amount being produced. Allowable production is based on potential, therefore, the potential is used for calculating the factor.

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group shows a saving of $.076 a barrel as compared with adjacent wells not packed. This cost does not include the loss sustained by several wells in which collapsed and cut-out oil-strings forced their shut-down.

In all areas where extensive gravel-packing has been employed, the gravel-packed wells show a greater cumulative production and a better-sustained production rate than other wells during the last two years. This is due partly to the reduction of down-time, but may also be due partly to the better condition of the wells gravelled and improved drainage because of the larger hole.

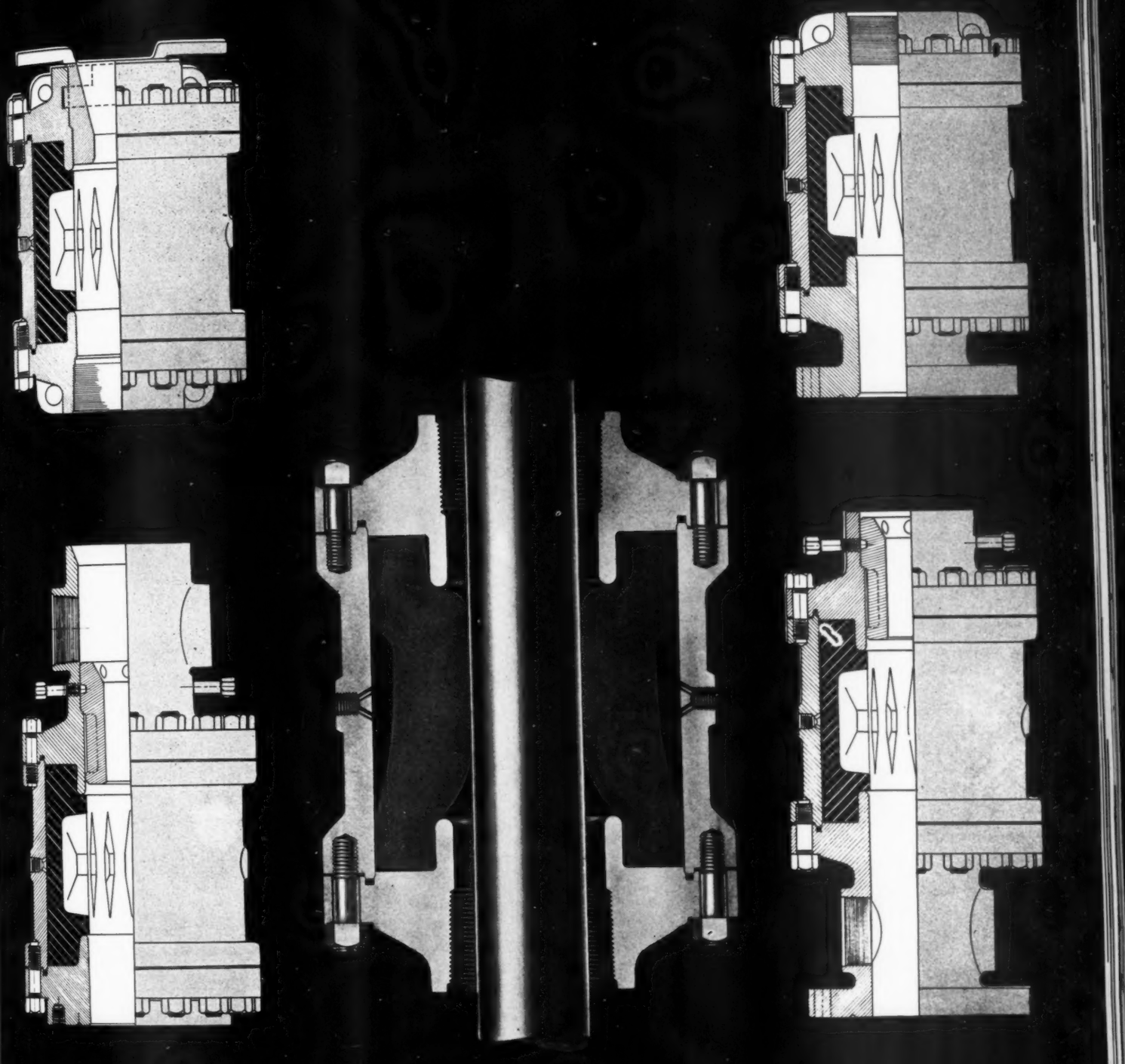
In wet wells conventionally completed, into which sand tends to run when the fluid-level is pumped-down, the ability of a gravel-packed well offers a distinct advantage.

Table I compares pumping jobs and lost production of gravel-packed with the same data on other wells in the Midway district, Kern County, California.

During the development of gravel-packing every effort has been made to reduce the cost of the operations of undercutting the zone, preparing the hole, and placing the gravel and liner or screen. Several of the initial completions required expenditures as much as 15 percent greater than the cost of drilling a conventional well. Extra cost for most of the wells probably averages 10 percent of the total drilling cost. Improvement of technique, planning, and smaller hole diameters within the zone have accomplished results in wells lately gravel-packed that indicate the cost may be reduced to as low as 3 to 5 percent of the total cost to drill and complete a well.

Operators in California are enjoying savings in operating costs on 8000 bbl. of approximately $350 daily. This saving is expected to pay for the cost of gravel-packing in a relatively short time and yield a considerable profit. Furthermore, it is already evident in a period of eight months that in at least a few instances in the Wilmington field, gravel-packing has preserved the life of a $40,000 investment, which otherwise might have been lost.

A typical portable rotary rig for drilling slim-hole wells



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Developments and Trends in the Natural Gasoline Industry

By J. W. VAIDEN, Manager,

and

F. E. FISHER, Chief Chemist,

Natural Gasoline—Natural Gas Division, Skelly Oil Company

THE remarkable developments in the petroleum industry in recent years are making it difficult to gauge the progress of any certain phase of the industry during a year's period. Oil and gas production, refining, and natural gasoline manufacture are becoming more closely interlocked. Better methods of oil and gas production affect greatly the composition of the gas going to the gasoline plant. Proration of oil and gas production by state regulatory bodies and unit block control of producing areas by the producing companies have resulted in problems requiring the close coöperation of the producer and the natural gasoline manufacturer for optimum utilization of all the useful constituents of the gas and oil. Repressuring or return of residue gas to the producing sand has also brought about a condition requiring joint consideration of operating problems by the producer and the gasoline manufacturer.

The use of natural gasoline by the refiner and the rapidly increasing use of the polymerization process, with its attendant requirement for butane, has increased the interest of the natural gasoline manufacturer in butane manufacture. The problem is somewhat complicated by the fact that the increase in production of polymer gasoline may decrease, to some extent, the need for natural gasoline by the refiner for increasing the volatility of his motor fuel. It must be remembered, however, that the refiner will need natural gasoline or butane from an outside source to replace the butane and butene that he polymerizes out of his own stock.

The natural gasoline industry is constantly faced with problems that must be solved by the natural gasoline manufacturer himself without much assistance from the rest of the industry. Since its inception the natural gasoline industry has been dependent to a very large extent upon the refiner for disposal of his product. The natural gasoline manufacturer, through individual efforts and those of his trade associations, has pointed the way to better motor performance for both the refiner and the motor car manufacturer. The refiner is leading the pace at the present time due to his progress in manufacture and adoption of new and improved methods. The refiner has the advantage of having in his raw material many constituents for the production of desirable components of motor fuel. He has found that he can meet a large proportion of his requirements for volatility by the proper utilization of his raw material. The tremendous amount of research work that has been done by the refiner and allied chemical industries has resulted in the more efficient processing of crude oil and an increased supply of product satisfying the anti-knock requirements for motor fuel.

Thus the market for the product of the natural gasoline plant seems to be decreasing rather than increasing. The effect of this situation has not been greatly felt, as yet, and the rapid change in manufacturing methods and requirements of utilization may reverse the situation before the market is too seriously affected. For instance, the recent increase in the anti-knock rating of third grade motor fuel to 67 octane number indicates a possible increase in use of natural gasoline in this fuel on account of the inherent anti-knock value and good lead susceptibility of the natural gasoline in such a blend.

J. W. VAIDEN

received a chemical engineering degree from Alabama Polytechnic Institute in 1921 and for several years thereafter taught mathematics—Was employed by the Skelly Oil Company in 1924, initially being engaged as a linewalker, later as gasoline plant engineer, then plant superintendent—When in 1933 the gasoline plants of the company were placed under the jurisdiction of the Production Department he was made manager of natural gasoline manufacture—In 1936 he was elevated to the post of general superintendent of the Natural Gasoline-Natural Gas Division and a year later to the position he now occupies.

A photograph and biographical sketch of Mr. Fisher, co-author of this article, appears elsewhere in this issue of *The Petroleum Engineer* in connection with another article by the same writers.

Advances In Plant Design

A plant has been built in South Texas, processing 6,000,000 cu. ft. of wet natural gas daily by a refrigeration process using propane as the refrigerating medium. Some 15,000 gal. of 18-lb. vapor-pressure gasoline is recovered daily. The designer of the process believes it has special application to the economical and efficient recovery of propane and butane as well as gasoline by operation under appropriate pressures and temperatures. This process incorporates dehydration of the gas stream prior to condensation in order to eliminate hydrates and freezing difficulties.

Another application of refrigeration for the recovery of the lower hydrocarbons is in the vapor-rectification

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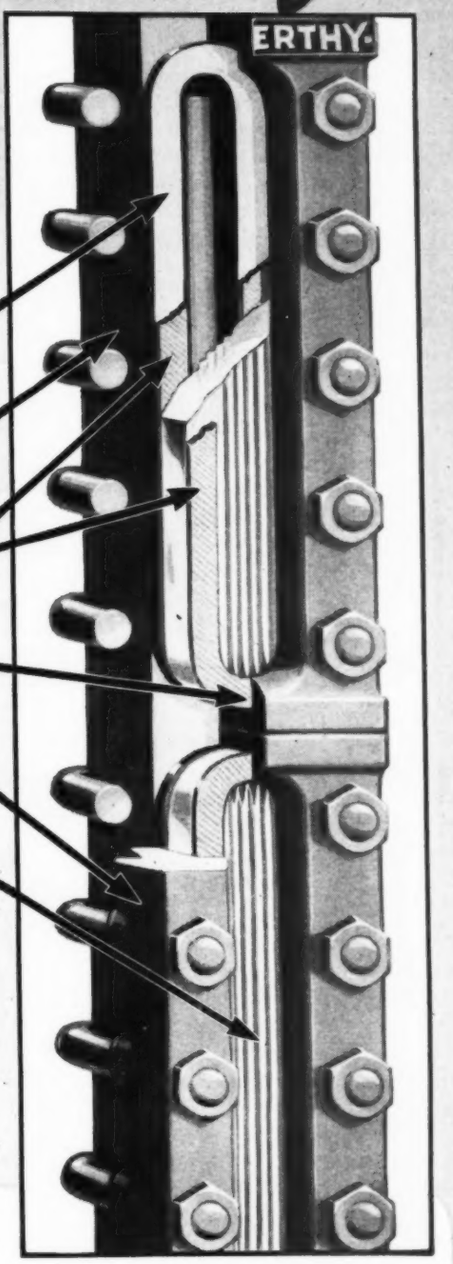

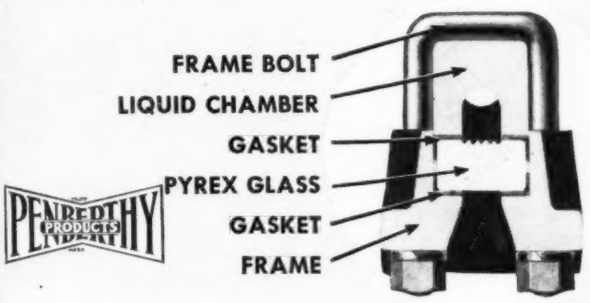

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process. Plants installed in the East Texas fields have shown very efficient recovery of propane and butane. In both of the above processes the designers assert installation and operating costs are lower than in the conventional absorption or compression-absorption plant.

Refrigeration has been adopted by a number of compression, absorption, and combination compression-absorption plants as a means of increasing the recovery of the lower and more volatile hydrocarbon compounds. Low temperature is almost a necessity if efficient recovery of propane and butane is desired at nominal pressure. Vapors and condensate must also be cooled if the recovered products are to be retained.

Greater attention is being paid to cooling and heat exchange. More efficient cooling towers, condensers, and coolers are replacing older and less efficient designs. In fact, the general trend of the industry during the last year in operation of plants has been toward the elimination of losses to obtain higher efficiency in operation.

Of considerable significance is the increasing trend toward the use of high-pressure equipment. Compression and absorption are being conducted at higher pressure in order to take advantage of reduced oil rates and the higher efficiency of extraction of the lower hydrocarbons. Fractionation or stabilization is also being effected at much higher pressure than before in order that the more volatile constituents may be isolated for use.

The higher operating pressures have brought about their own problems, not only in the design of equipment but in operation. The formation of gas hydrates under high pressure and low temperature conditions when water is present in the gas has necessitated the installation of dehydrating processes in several instances. Hydrate formation has been studied intensively and the results of the investigation, although far from complete, have supplied the industry with sufficient information regarding the formation of the hydrates to enable proper steps to be taken for the elimination of the trouble. Numerous dehydrating processes have been developed and are being closely watched by those confronted with such problems.

Polymerization has not yet been adopted universally by natural gasoline manufacturers. Although satisfactory results are reported in the few installations of the process in connection with natural gasoline plants, the cost of the equipment, the comparatively large size of the plant, and the high cost of operation have made the economic picture somewhat unfavorable for the average gasoline plant installation.

Considerable progress has attended the study of the sweetening or treating of gasoline and it appears de-sulphurization of gasoline may soon be economically practicable. A definite relationship has been shown between sulphur content and lead susceptibility; the sulphur content of the gasoline is therefore of considerable importance to the natural gasoline manufacturer and refiner as a means of reducing the cost of tetraethyl lead treatment.

Numerous improvements continue to be made in equipment of all kinds for the natural gasoline industry. Such contributions may eliminate to a considerable extent the hesitancy of the natural gasoline manufacturer to recognize obsolescence. The improvements in operation using the newer equipment are sometimes sufficiently outstanding to merit their immediate adoption even in these days of low profits.

Absorption Oil

More interest has been shown of late in absorption oil. Oil of low molecular weight is gradually supplanting the heavier oils used in the past. Higher recovery of the lower hydrocarbons is usually possible using a lighter absorbing medium, and cooling and pumping problems are greatly simplified. The reconditioning of absorption oil in service has also been adopted in many plants during the last year. Improvements in testing methods are needed to enable the absorption plant operator to determine more accurately the efficiency of plant performance. The testing methods in use at the present time offer little information concerning the propane and butane recovered, or the amount of so-called fixed gases that go into solution in the absorption oil and must be removed at some point in the system.

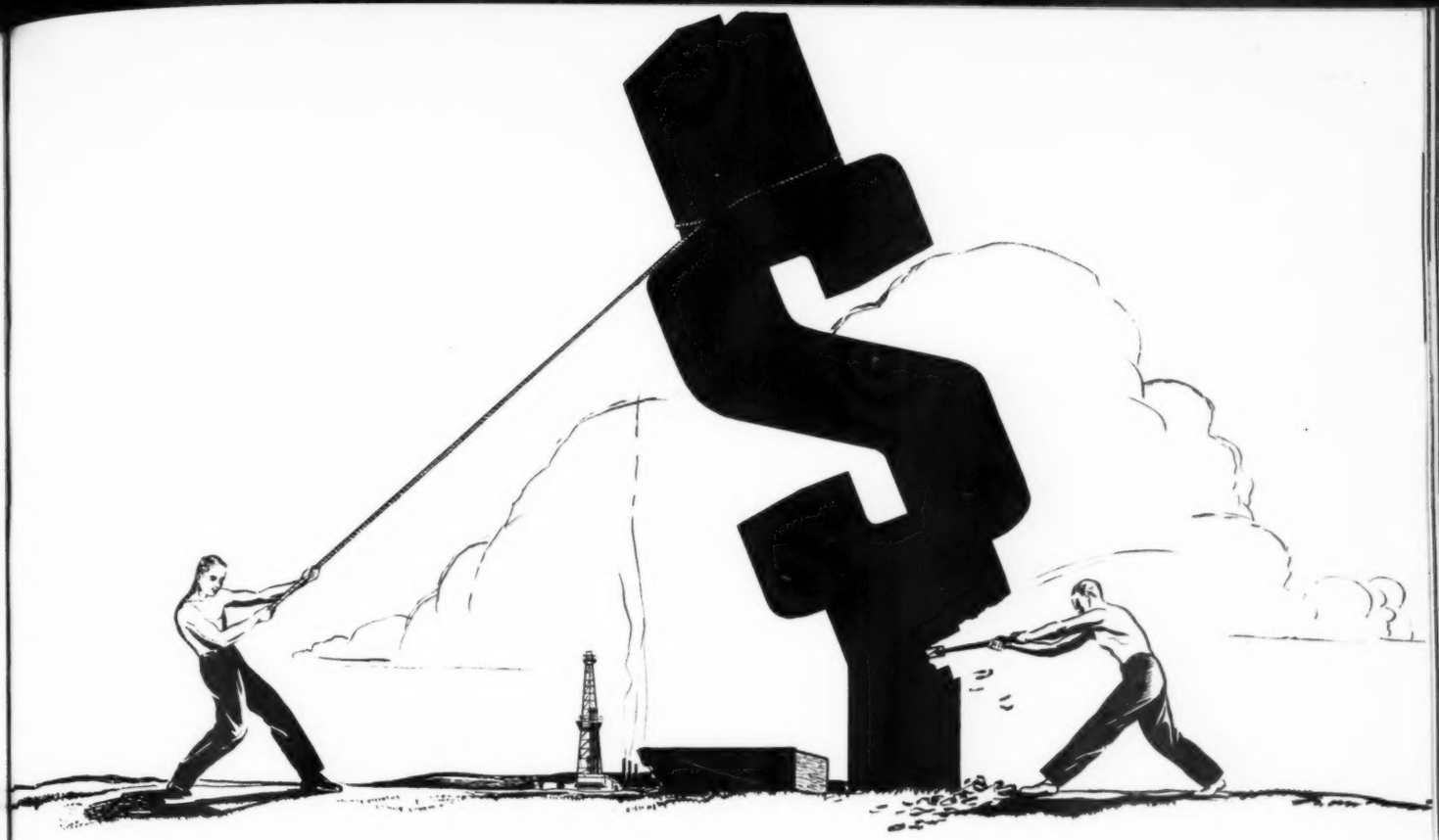
Improvements have been made in the methods of testing natural gas for gasoline content both by compression and by charcoal methods, and will be adopted soon as standard methods of test by the industry. Repressuring, or the return of residue gas to the oil producing sand has had considerable impetus in some fields. Such work has received close coöperation between the natural gasoline manufacturer and the oil producer. Problems of special nature have arisen in some cases, however. Pressures necessary for return of the gas to the oil sand are usually quite high. In some cases pressures have reached values at which it was believed impossible to extract gasoline. Successful operation, however, of an oil absorption plant has been shown possible at pressures as high as 1500 lb. per sq. in.

Safety In Operation

Many operators in the industry have been concentrating upon safety in operation. New methods of approach to the problem have resulted in very favorable results and the natural gasoline industry is taking its place among the foremost in industry for its freedom from accidents.

Interest is constantly increasing in research leading to the development of new products from the raw materials available and of new markets for the old products. The refining industry is rapidly adopting the methods of the chemical industry. Instead of using the products normally obtained from petroleum, the refiner is rapidly adopting chemical processes whereby the natural products are changed into synthetic materials far different from the original and which, in many cases, offer greater returns to the manufacturer than the natural petroleum products.

The same procedure is open to the natural gasoline industry to a considerable extent. Its problems are different from that of the refiner only to the extent of the available number of individual hydrocarbon compounds composing the raw material. As produced, natural gasoline consists almost entirely of paraffin hydrocarbons of from two to seven carbon atoms. Of these, propane, iso- and normal butane, iso- and normal pentane, hexane, and heptane are being manufactured as commercially pure hydrocarbons with a small amount being made in C. P. purity. Propane and butane are used largely as domestic and industrial fuels although markets are developing for large quantities of butane as feed for polymerization plants. In some cases this requires the separation of iso-butane of high purity. Iso-pentane, although of considerable value as an ingredient of high octane-number motor fuel does not command the price that its manufacture should justify. This is probably because the relatively high vapor-pressure of the product limits the volume that can be included in a motor fuel of specifications such as



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aviation gasoline. The higher hydrocarbons are used largely as solvents or for further chemical processing.

If the natural gasoline manufacturer were to adopt the methods of the more progressive refiner, and convert his raw product into a more valuable one by some of the many processes available to the industry today, it seems entirely possible that he would find himself free, to a considerable extent, of low-priced seasonal and uncertain markets.

By dehydrogenation of the paraffin gases, by polymerization, or alkylation, and by hydrogenation, the paraffins can be converted into motor fuels of high anti-knock quality. Thus, by application of a suitable process, natural gasoline may be changed into a premium product rather than a low-priced product offering little profit in its manufacture.

Aviation gasoline should benefit from alkylation of low-boiling isoparaffins and from isomerization of straight-chain hydrocarbons to isoparaffins or cyclic hydrocarbons. The rapid increase in aviation activity, particularly of military aviation, should result in an increased demand for high-octane fuel. The natural gasoline manufacturer has the raw material to supply such needs if he will convert it into the form required.

To carry out these operations, tremendous capital investments are required in equipment and in research bearing on the new products. This results, of course, in high interest and depreciation charges that increase manufacturing cost. Offsetting this cost is the increased price obtained for the new products and the establishment of a more secure market. The natural gasoline manufacturer who finds himself unable to install new equipment, or to modernize his old plants, will soon find himself in a difficult position with little hope of continuing operation in the face of radical changes in the industrial picture. New processes are being constantly developed and the selection of the most profitable process to fit the individual case is a difficult problem for the manufacturer. Progress and developments are being carefully watched by all of those interested, but the tremendous amount of research that is being done by the petroleum and allied chemical industries results in an ever-increasing stream of new processes of value to the natural gasoline manufacturer. A study of the patents granted weekly on such processes will give some idea of the amount of work being done.

"Aromatization," or cyclization, is still in the experimental stages so far as the literature discloses, but such processes may develop into considerable importance to the industry.

From an overall viewpoint, it is evident that the natural gasoline manufacturer is somewhere near the crossroads. Either he must be satisfied with little or no profit in his operations or he must depart from traditional practice and turn his attention toward the newer methods and processes that show possibilities of profit.

Carbon-Black Industry Experienced Unsatisfactory Year in 1938

COMPARED with 1937, domestic sales and exports of carbon black declined 20 and 9 percent, respectively, states the U. S. Bureau of Mines; however, the most discouraging feature of the year was the behavior of prices, which declined to unprecedented low levels. Although production was curtailed, stocks at plants increased substantially.

As noted a year ago, carbon-black prices weakened abruptly at the end of 1937. Two additional reductions in spot prices were made in January, 1938, bringing the standard zone price to less than 3 cents per lb., the generally accepted production cost. The average value at the plants as reported by producers declined from 3.41 cents in 1937 to 2.41 cents in 1938. The average export value was better maintained, nevertheless it declined from 4.72 cents in 1937 to 4.51 cents in 1938.

The decline in output in 1938 was quite general throughout all the producing states, Oklahoma being the principal exception. Louisiana's output showed a material decline (40 percent) but that of Texas nearly held its own, declining only from 421,068,000 lb. in 1937 to 417,104,000 lb. in 1938. Production in the Texas Panhandle declined in 1938 for the first time since 1932, but a material gain in output was experienced in West Texas.

Total sales of carbon black in 1938 amounted to 411,442,000 lb., or 16 percent less than in 1937. Domestic sales in 1938 totaled 243,474,000 lb., or 20 percent less than in 1937. Of the domestic sales the rubber trade took 89 percent, ink companies 6 percent, paint companies 2 percent, the remaining 3 percent being classed under sales for miscellaneous purposes. These data indicate chiefly a small increase in the relative importance of sales to rubber companies at the expense of sales for miscellaneous purposes.

After increasing for three successive years, exports of carbon black declined in 1938, when about 168,000,000 lb. were shipped abroad, compared with about 184,000,000 lb. in 1937. The reasons for the decline in exports in 1938 are obscure; probably the principal reason was a general decline in activity at rubber plants abroad rather than changes in military policy. Important increases in exports by countries were notably few in 1938, the outstanding one being of about 40 percent over 1937 credited to Italy. The United Kingdom continued as the leading foreign customer, France was second, and Germany third. Although Germany's imports from the United States declined in 1938, it is doubtful if this was related to the production of substitutes. The low prices for carbon black in 1938 were not conducive to substitution, even in Germany.

Carbon-black producers burned 324,950,000,000 cu. ft. of natural gas in 1938, for which they paid about 1¼ cents per M cu. ft. After attaining a record of 1.50 lb. per M cu. ft. in 1937, the yield declined to 1.47 lb. in 1938. Doubtless, this decrease in the yield was related to the material decline in the production by processes other than channel, some of which recover as much as 10 lb. per M cu. ft. of gas burned.

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Progress and Trends in High-Pressure Oil Stabilization and Natural

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By E. O. BENNETT
Chief Petroleum Engineer, Continental Oil Company

PRESSURE-maintenance operations are now accepted by many efficient operators as being a necessary procedure for increasing ultimate recovery and lowering operating cost of oil production.

There is no mystery about pressure-maintenance practice. It is simply the application of fundamental engineering knowledge to production methods for the greatest utilization of material and energy stored-up by nature in deep-producing zones.

Pressure maintenance is today being applied in two distinct types of operations. The first is in normal oil recovery. The second is in connection with the recovery of a condensate, commonly miscalled distillate.

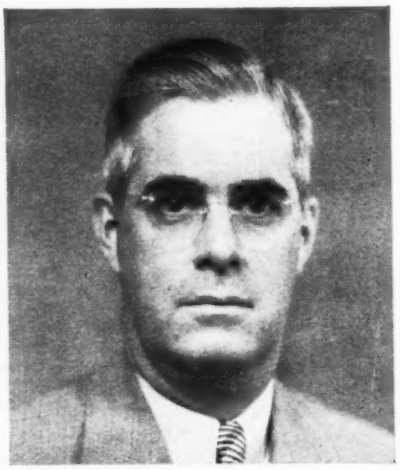
Several oil pools in various parts of the country have been placed under pressure maintenance since high-pressure operations were initiated in Louisiana early in 1936. The fear and danger of high-pressure gas operations are more apparent than real, as with proper design and control, highly favorable results are being obtained. Much has been written of pressure-maintenance operations during the last two years, and no attempt will be made at this time to enter into details. Advantages resulting from pressure-maintenance operations are reiterated, however, to stress further the advantages and economies available to the operator who is willing to take advantage of them. These advantages are:

(1) Reduction of lifting cost by prolonged flowing life.

(2) Avoiding capital investment for pumping equipment in high-pressure pools. Pressure-maintenance machinery in a pool of moderate size will cost approximately 25 percent of the cost of the pumping equipment otherwise required, and normally a larger volume of oil will be produced.

(3) Production under pressure-maintenance operations will usually be accompanied by less water, and this will simplify and reduce the cost of treating problems.

(4) Gas returned to the formation to supply energy for moving oil is saved for future fuel markets and may even provide a supply of raw material for conversion into new and desirable products in the future. Developments in catalytic processes and thermal reforming are far too rapid to permit the waste of hydrocarbons in any form. There are now excellent possibilities that the gas produced with oil will be as valuable as the oil itself.



E. O. BENNETT

graduated from Stanford University in 1917 and the same year became associated with the Standard Oil Company of California — Was technical advisor for the U. S. National Advisory Committee for Aeronautics from 1918 to 1919 — Returned to Standard Oil Company of California in 1919—Was petroleum technologist for the U. S. Bureau of Mines from 1924 to 1926—Chief petroleum engineer for Marland Oil Company from 1926 to 1928—Since 1928 has been with Continental Oil Company as chief engineer, assistant manager of drilling and production, and, currently, chief petroleum engineer.

Recovery of condensate formerly was by simply producing gas through a separator, collecting the liquid, and wasting the lighter hydrocarbons. Recovery methods today are highly efficient and economical and are applied without excessive gas waste or reservoir-pressure depletion.

Installation of an oil-recovery, pressure-maintenance project requires a thorough knowledge of the reservoir conditions. This information should include a thorqugh core analysis survey and electrical logging from which accurate stratigraphic cross-sections may be compiled. Sections along at least two axes of a pool or structure should be made. A thorough geological analysis should be made to locate properly wells for gas injection with respect to fault planes, if they exist, to maintain pressure throughout the pool at a minimum differential between wells, and to prevent voided areas.

A carefully planned production program must be followed at all times to maintain a balance between gas, oil, and water in the formation to obtain proper lateral drainage of oil instead of too great a vertical drainage of gas and water. The allowable production rate must be governed by proper pressure balance and by subsurface migration of gas, oil, and water. The fact that pressures at or near those originally existing may be maintained does not signify that extremely high ratios of production may be permitted.

Within the last two years several plants have been constructed and placed in operation for recovering condensate from gas wells. Most of these plants have been built in conjunction with pressure-maintenance plants for saving the gas that otherwise would be wasted and for increasing the condensate recovery. State conservation commissions and regulatory bodies have approved such types of operation.

Retrograde Phenomena

Considerable mystery seems to have shrouded the entire program of condensate recovery through the use of highly technical terms to describe "retrograde phenomena." The knowledge of the phenomena is not new, as it was discussed by Kuenen in 1895[1].

An understanding of the fundamental behavior or the phase relations of gases under different conditions of pressure and temperature is necessary for the proper design of specific plant equipment for condensate recovery under retrograde condensation. The

[1]Kuenen, "On the Condensation and the Critical Phenomena of Mixtures of Ethane and Nitrous Oxide," *Philosophical Magazine and Journal of Science*, Vol. XL, 5th Series, pages 173-194, July-December, 1895.

Maintenance in Conjunction With Crude Gasoline Recovery Operations

following excerpt[2] from an article by J. J. Carter and C. E. Webber clearly explains the phenomena:

"A brief explanation of the phase relations of a sub-surface gas (Fig. 1) may aid in understanding the behavior of a gas when subjected to changes in pressure or temperature. This diagram is not exact in its dimensions, but merely shows a general trend toward which naturally occurring hydrocarbon mixtures adhere. Definite experimental curves have been published by Lacey and his co-workers[3] and from his data together with that by Kay[4] and Katz[5] we can arrive at some conclusion as to the shape of the diagrammatical relations of a complex hydrocarbon system. The portion of the curve AC is the boundary between the single-phase or liquid region and the two-phase or vapor and liquid region. This line is the vapor pressure or bubble point line. The line CB is the boundary between the same two-phase region of vapor and liquid on the inside and the single-phase vapor region on the outside. This line is called the 'dew point curve.' At the point C, we have the critical point where the properties of the vapor and the liquid become continuously identical, and they cannot be distinguished from each other.

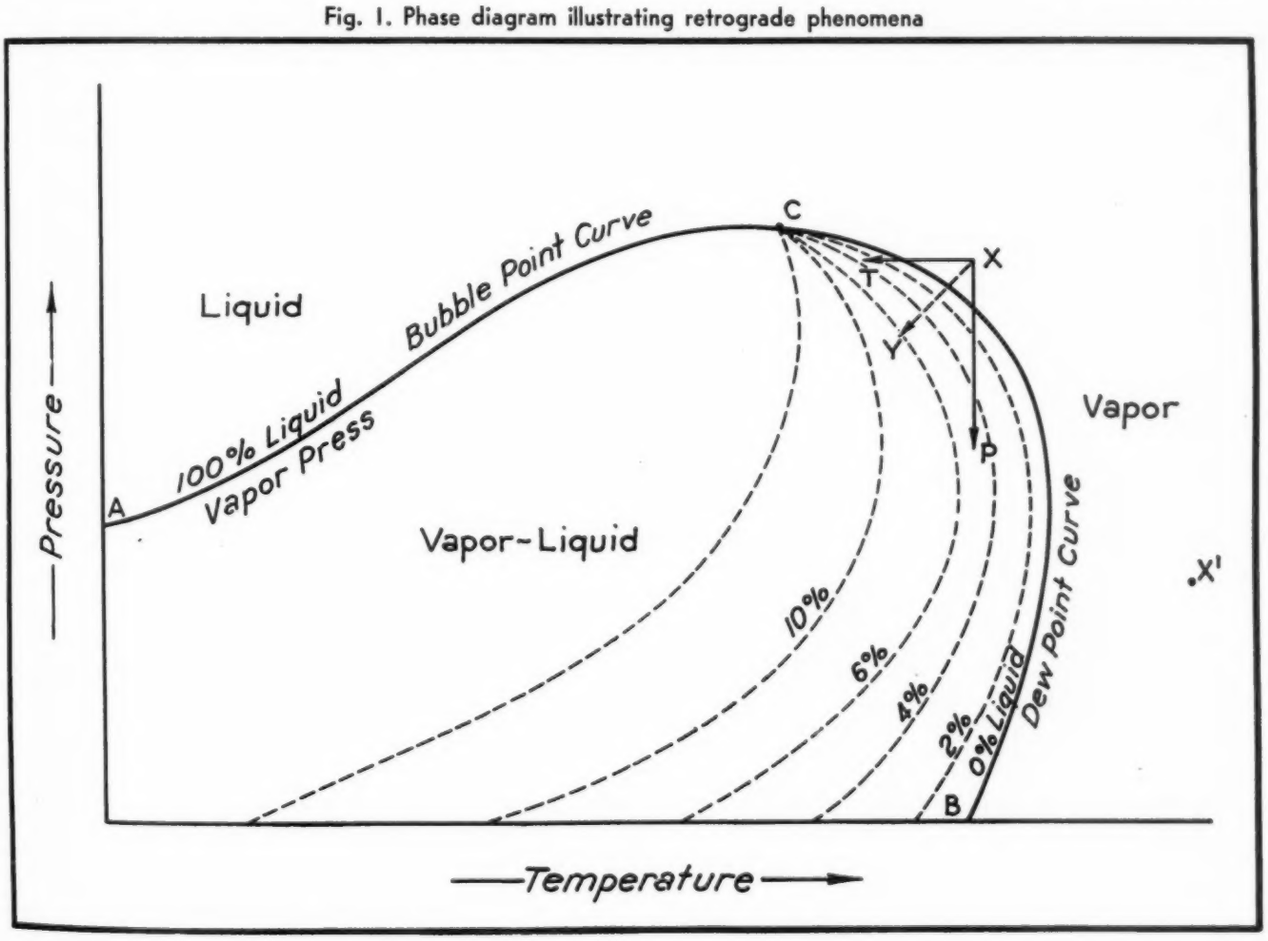
"We now have three sections of this diagram: above the line AC is liquid; to the right of C and outside of CB is pure vapor; and inside the line ACB is a mixture of vapor and liquid. The dotted lines represent the percentage of liquid in the liquid-vapor region.

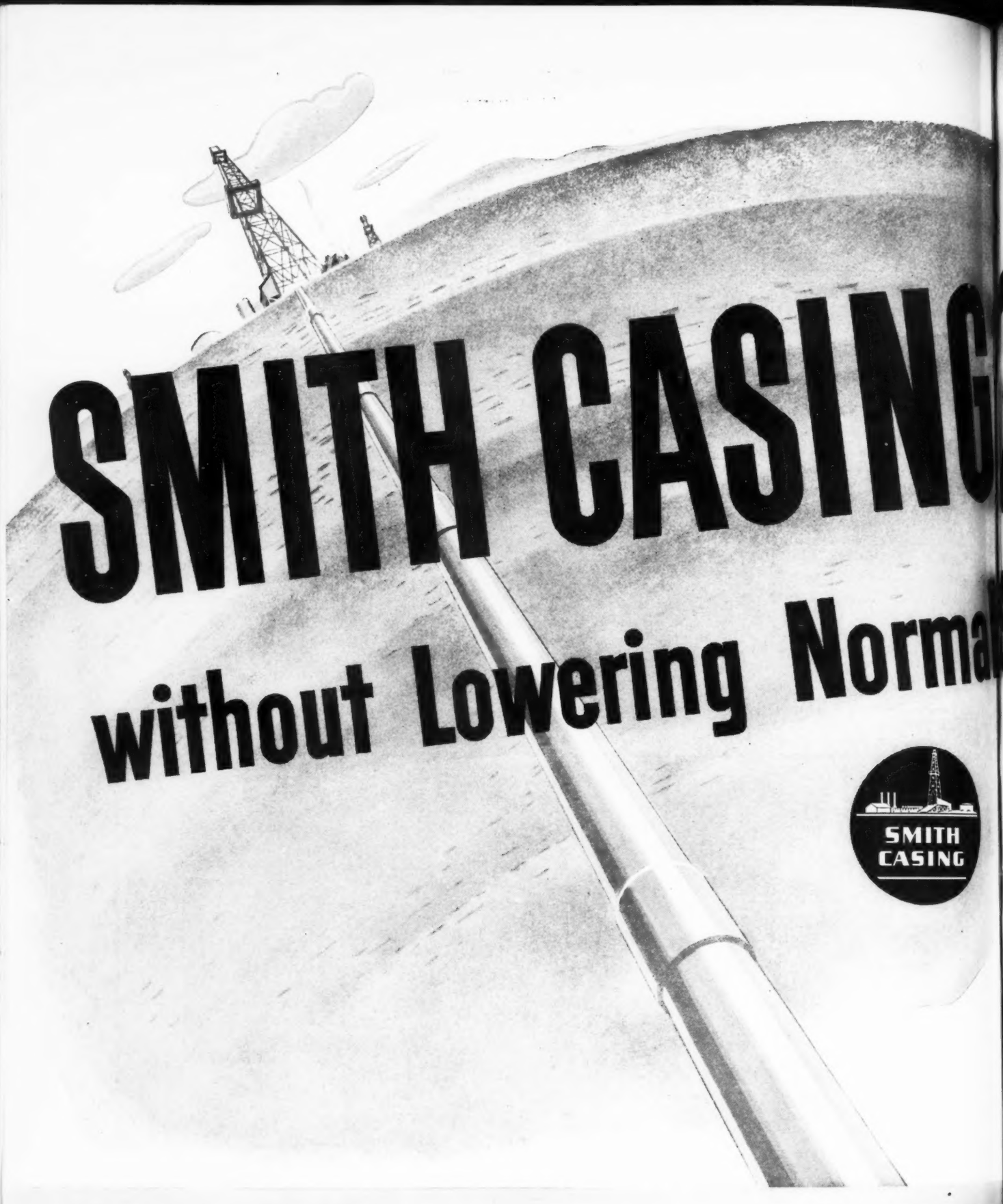
"Wells of the type exemplified by the Texas Panhandle district would have reservoir conditions falling to the lower right of the dew-point curve CB, shown by the point X[6]. As can readily be seen, any change in pressure would not affect the phase behavior of this fluid because throughout any pressure range at the given temperature the fluid always remains a gas. Any appreciable temperature reduction would, however, cause the condensation of liquid because the conditions would then fall to the left of the dew-point curve CB and would lie in the two-phase region. Practically all of the recent gas wells in the Texas and Louisiana Gulf Coast produce liquid and are of the type shown by the point X.

[2] *Refiner and Natural Gasoline Manufacture*, Vol. 18, No. 5.
[3] Sage, Schaafsma and Lacey, *Ind. Eng. Chem.* 26, 214 (1934).
[4] Kay, *Ind. Eng. Chem.* 30, 459 (1938).
[5] Katz and Hackmuth, *Ind. Eng. Chem.* 29, 1072 (1937).
[6] H. S. Bean, Research Paper No. 170, *Bureau Standards Journal of Research*, Vol. 4 (1930).

(*Continued on Page 54*)

Fig. 1. Phase diagram illustrating retrograde phenomena





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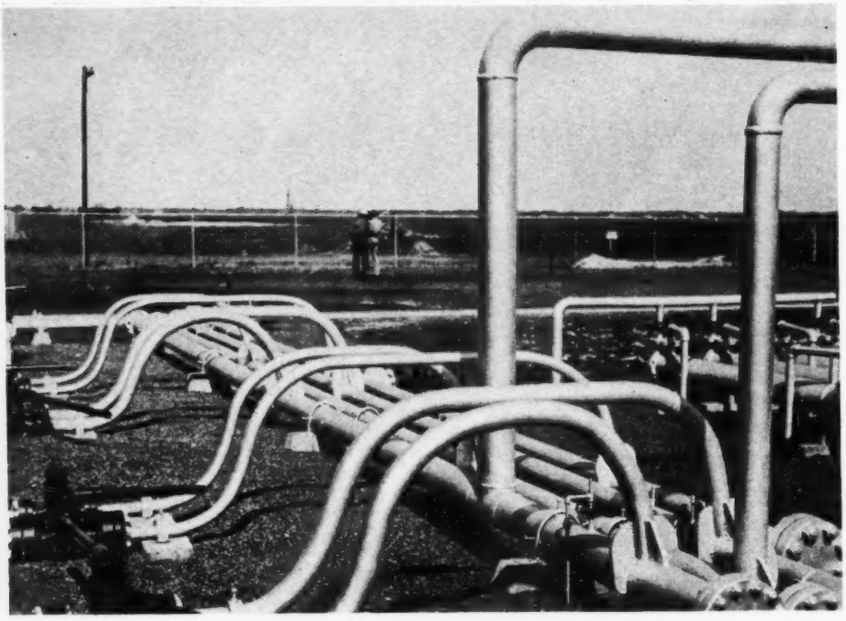

Arrangement of headers at Tepetate plant of Continental Oil Company

(*Continued from Page 51*)

"We have recently learned that wells of the gas-distillate type contain, in the reservoir, a gas which from subsurface temperature and pressure measurements, is shown by a point X or on the upper portion of the line CB. If the pressure on this gas is allowed to drop, it will cause the condensation of liquid because the pressure will now be at a point P which is in the two-phase region. This condensation of liquid is called retrograde condensation. A reduction of temperature of the gas will also have the same effect because we would drop to a point T which is also in the two-phase region. A combination of these two factors, pressure and temperature reduction, results in a condition shown by Y and is therefore to be avoided in all cases if we expect to have a true gas flowing from the well head.

"Of course, it is impossible to flow a well without some reduction of pressure or temperature from that in the subsurface formation and consequently most wells do carry a certain small amount of entrained liquid. The amount of this entrainment which can in some cases cause slugging, will depend upon magnitude of the pressure and temperature reductions."

From the above discussion it is shown that the single-phase vapor or gas from a well can be changed to a two-phase liquid-gas substance by reducing the pressure or temperature, or both, to cross the bubble point—dew-point curve ACB.

To lower the temperature without reducing the pressure requires refrigeration. This may be accomplished by water cooling, propane expansion, ammonia refrigeration, or by other mechanical refrigerating cycles.

A study of the accompanying diagram shows that the change from the vapor phase to the vapor-liquid phase is also readily accomplished by a reduction in pressure only at a constant temperature. The exact magnitude of pressure drop is a function of the composition of any specific gas and will vary in different pools or in different sands in the same pool. The question of whether the condensation should be accomplished by temperature reduction or pressure reduction, or both, can only be determined by testing wells producing the gas and ascertaining the results of each method. Then, by knowing the cost of reducing the temperature through a given range and the cost of recompressing the gas after it has been reduced through a certain pressure range, or any combination of the two, the most economical plant may be designed.

The optimum range of pressure reduction for maximum condensate recovery for average high-pressure Gulf Coast gases seems to be between 800 and 1200 lb. per sq. in. At reduced temperatures, higher pressures can be maintained for the same recovery. Condensation by pressure reduction has been long known, but not called by the name retrograde.

Thompson states[7]:

"Most of the great gas fields yield a gas containing very little condensable products and even the very large initial gas flows on the oil fields are composed of methane. At times, however, moderately large quantities of condensate are precipitated in the mains leading from gas wells, and 'bleeds' must be arranged for its removal. A large gas well at Wertz Dome, Wyoming, with a closed pressure of 1,800 bbls. at 3,425 feet and an initial flow of 40,000,000 cubic feet daily gave a drip of 4,000 to 10,000 gallons of 66°B. (sp. gr. 0.717) gasoline daily and for years delivered 30,000,000 cubic feet of gas daily to Casper 92 miles away. A well 3,700 feet deep at Okotoks, near Calgary, Canada, with a closed pressure of 1,200 pounds per square inch gave a drip of 20,000 gallons of 72°B. (0.693 sp. gr.) daily from a 4-inch main which led the gas away."

The condensate above referred to would be the liquid of the liquid-vapor phase formed when the pressure was reduced, as shown by the line XP on the chart.

Higher-Pressure Plants

Condensate recovery at pressures approximating 1000 lb. was accomplished for many years before the word retrograde was in general use. Two-stage separation was employed in 1935 in a high-pressure Louisiana field and condensate was recovered at approximately 1200 lb. per sq. in. This was accomplished by pressure drop and the natural refrigeration that accompanies it.

In addition to pressure- and temperature-controlled condensate-recovery projects, much work is now being done on high-pressure absorption of the condensable components of the gas. Plants are successfully operating at a pressure of 1200 lb. per sq. in., and 1500-lb. plants are now being designed. The economies of high-pressure absorption as compared to pressure- and temperature-controlled condensate operations have not yet been determined as there are too few installations. Pressure-maintenance operations in connection with gasoline-extraction and condensate-recovery plants indicate that absorption at extremely high pressures will be desirable and economical.

The value of pressure maintenance in conjunction with condensate recovery is now accepted by the industry and is being generally adopted. Most of this recognition has taken place since 1936.

Field stabilization of high gravity crudes has proved very desirable and economical but has not been as generally accepted as pressure maintenance. Its general adoption is, however, indicated for future operations.

[7]Thompson, *Oil Field Exploration and Development*, 1925, Vol. 2, p. 1129.

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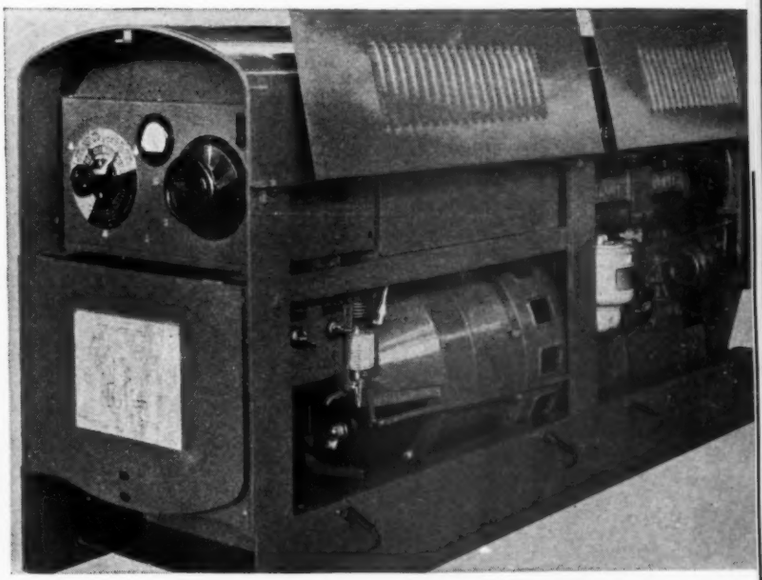

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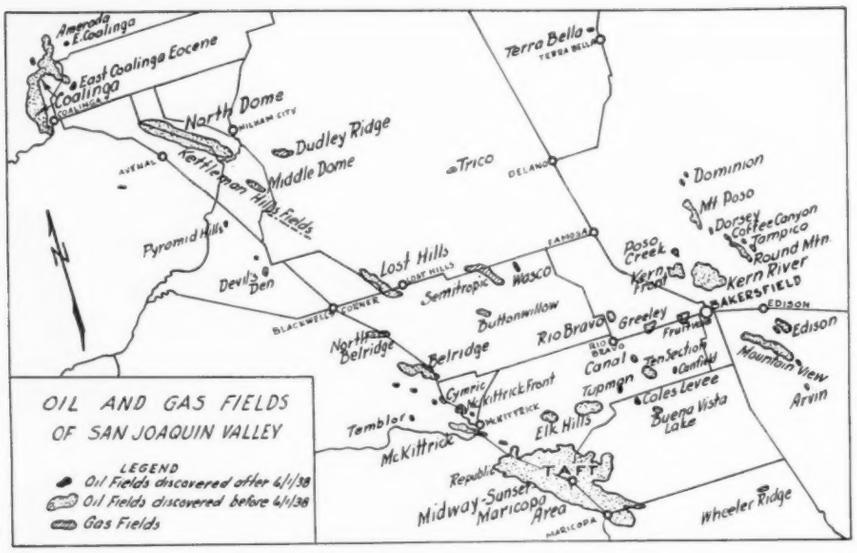

Old and new fields in San Joaquin Valley

Advancements in Production Practices in California

By WALLACE A. SAWDON
Pacific Coast and Foreign Editor

CALIFORNIA'S estimated known oil reserves on January 1, 1939, were slightly more than three billion bbl., an increase of 4 percent during the calendar year 1938. The increase in reserves was somewhat in excess of production during the year and was a result of the discovery of new fields, the discovery of new zones in old fields, the extension of productive areas, and corrections being made for certain areas as a result of more accurate data becoming available.

During the year ending June 30, 1939, five new fields were discovered. Four of these are in the San Joaquin Valley and the fifth is in the Newhall district near San Fernando. This does not include Wasco, which was discovered before June 30, 1938, but the reserves for which are included in those mentioned above. Of the four fields in the San Joaquin Valley, one is a recent discovery about five miles north of the East Coalinga Eocene field; it may be an extension of that field or a separate structure. The well was drilled by Amerada Petroleum Corporation to a depth of 8082 ft. It produced 4000 bbl. of 31-deg. A.P.I. oil per day and 14,000,000 cu. ft. of gas through a 44/64-in. bean. Discovery was made in April, 1939, and little yet is known concerning the extent of the productive area or whether it is a new field or an extension. Discovery was by combined geological and geophysical data.

The East Coalinga Eocene field, 5½ miles northeast of the town of Coalinga was discovered in July, 1938, by a joint Petroleum Securities-Seaboard-Honolulu test. The well was drilled to a depth of 6908 ft. Its initial production was 7900 bbl. of 32-deg. A.P.I. oil per day through a 38/64-in. bean. The tubing pressure was 1100 lb. and the casing pressure 1375 lb. A well was drilled later through 600 ft. of oil

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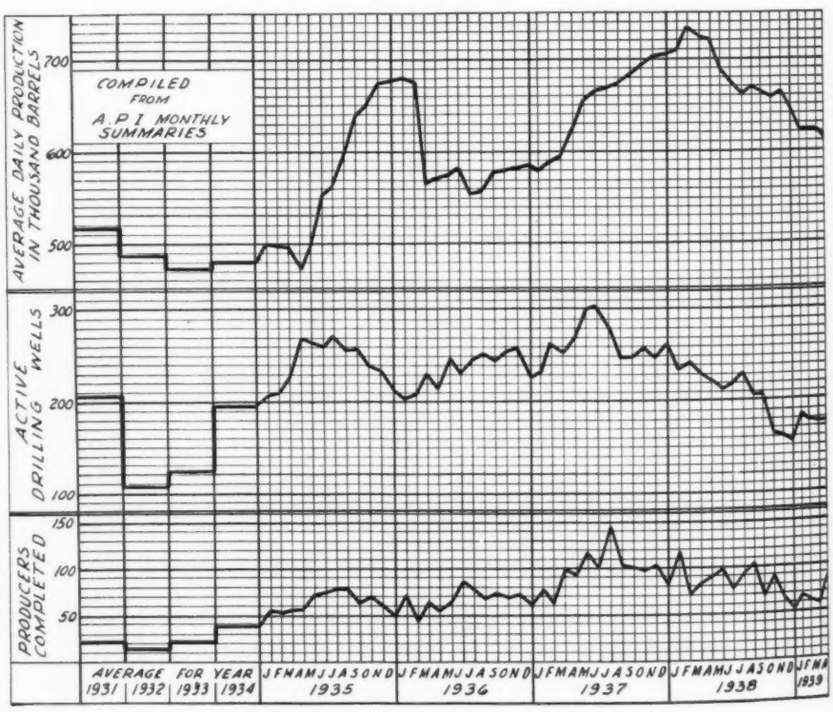


Chart showing production, drilling activity, and completed wells in California

(*Continued from Page 56*)

sand. Discovery was a result of field mapping and subsurface studies.

The new Aliso Canyon field is 6 miles northwest of San Fernando and was discovered in October, 1938, by Tide Water-Associated Oil Company. Initial production was 1200 bbl. of 24-deg. A.P.I. oil per day through a 40/64-in. bean, at 150-lb. tubing pressure and 1300-lb. casing pressure. The well was drilled to a depth of 5393 ft., production being from a sand almost 600 ft. thick. Discovery was by geologic field mapping.

Coles Levee field, 18 miles southwest of Bakersfield, was discovered by Ohio Oil Company in November, 1938. The well was drilled to a depth of 9365 ft. and came in for an initial production of 750 bbl. of 45 deg. A.P.I. oil per day and 4,000,000 cu. ft. of gas, flowing through a 48/64-in. bean. The tubing pressure was 475 lb. and casing pressure was 900 lb. Discovery was by reflection seismograph.

The Tupman or Richfield-Western field is about four miles northwest of Coles Levee field and was discovered in November, 1938, by Richfield Oil Corporation. The discovery well was drilled to a depth of 8677 ft. and first produced from more than 400 ft. of sand. Initial production was 3750 bbl. of 44-deg. A.P.I. oil through a 1½-in. bean, at 1000-lb. tubing and casing pressures. Because of a high gas-oil ratio the well was recompleted to produce from 128 ft. of sand. Gas production was thus reduced to approximately 50 percent of the initial flow. Discovery was by reflection seismograph.

New zones were discovered in the Greeley, Torrance, Montebello, and Long Beach fields. The most important of these was in the Greeley field where the new deep zone lying between 11,400 and 11,520 ft. correlates with the Vedder zone of Lower Miocene age, productive in the Rio Bravo field.

Two new gas fields were discovered. The Willows field is 135 miles northeast of San Francisco. One well was drilled by the Ohio Oil Company to a depth greater than 6000 ft. but was plugged-back and is producing 5,000,000 cu. ft. of gas per day through a 42/64-in. bean from a depth of approximately 2240 ft. The Potrero Hills field, 40 miles northeast of San Francisco, was discovered by Richfield Oil Corporation. The one well drilled was to a depth of 5334 ft. but was plugged-back to 3265 ft. from which depth it made 5,000,000 cu. ft. per day through a 16/64-in. bean.

In a recent paper[1] it was brought out that, although progress has been made, the present program of voluntary curtailment in California deserves greater success. The author states there are two distinct problems that should not be confused. One, the capacity to overproduce, requires that existing wells be equitably curtailed and that the rapidity of drilling additional wells in proved fields be reduced in conformity with the need for additional oil. The other, the increasing demand for oil and the relatively low position of our total known oil reserves, requires that every effort be expended to improve the moderate success of the last three years on the technique of finding oil. *Wildcat drilling activity in California should not be allowed to decline.*" (The italics are the author's.)

Even though the state's reserve is somewhat more than 12 times the present annual production, it must be remembered that it will take considerably longer than 12 years to get all the oil from the ground and that a higher ultimate yield will be obtained by improved methods that will probably necessitate less immediate production and more orderly development of present fields. This means more fields must be discovered to keep pace with the demand and at the same time allow for development and application of ever-increasing efficiency in production methods that, while not as dramatic as new drilling technique, are constantly being advanced.

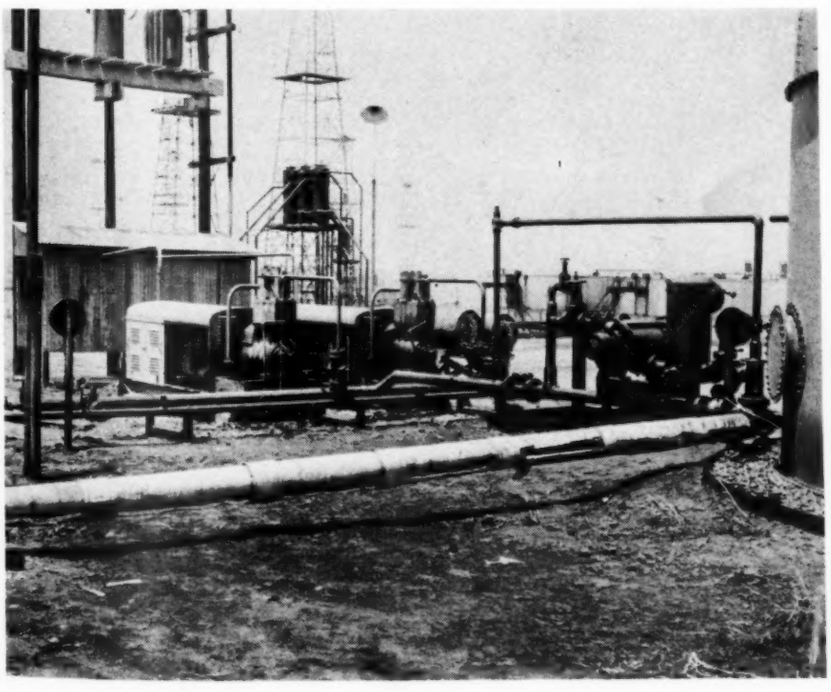
[1] "Additions to California Oil Reserves," by Harold W. Hoots, American Association of Petroleum Geologists Meeting, Oklahoma City, Oklahoma, March, 1939.

Pumping

Although the very deep wells of California—those below 10,000 ft.—are still flowing, there will come a time when oil from those depths will have to be lifted by artificial means. Gas-lift, when gas is available, likely will be utilized to the greatest extent for as long a time as possible. Considerable advance study is being given to meeting this problem when it arises.

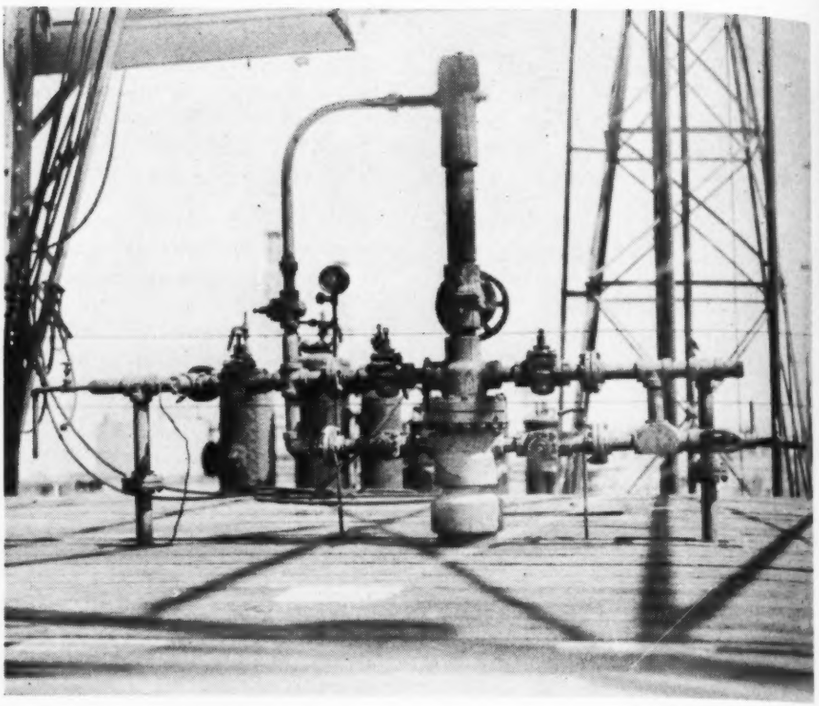
The deepest well pumped with rods is in the Rosecrans field. This well, producing from a depth of 8315 ft., is probably the deepest rod-pumped well in the world. It is producing approximately 90 bbl. of oil per day. The well was first equipped with a 1⅛-in. insert pump operated by a combination sucker-rod string consisting of 3500 ft. of ⅞-in., and 2190 ft. of ¾-in. rods. The maximum rod stress is 31,000 tion is a 6-cylinder, 60-hp. gas engine.

Considerable experimental work has been done on this well to determine maximum efficiency at this depth. After being pumped with rods for a time, a hydraulic pump was installed for a trial period, following which rods were re-installed. At the present time the hydraulic pump is again being used. Observations of performance are still being made and data obtained will prove of value in making installations under similar subsurface conditions at even greater depths. Several wells at Santa Fe Springs are being pumped by



Power station for a "gang" pump supplying power oil for nine wells

Surface equipment of a plunger-lift installation



rods from depths of 7000 to 8000 ft. Data on their performance have been accumulated over a period of years.

At El Segundo one well is being pumped from a depth of 7070 ft. by a 25-ft. pump using a 15-ft. stroke. In designing this long pump, stretch was taken into consideration, so that adequate seal and contact surface would be assured by providing ample space at top and bottom. The size of the plunger is 2 in. and the pump is operated with 2850 ft. of 1-in., 2010 ft. of $\frac{7}{8}$-in., and 2190 ft. of $\frac{3}{4}$-in. rods. The maximum rod stress is 31,000 lb. The rods are actuated by a pneumatic pumphead that utilizes a single-acting cylinder suspended over the hole. In this type of surface equipment air or gas supplied by a compressor can be used as a power medium; or, when available at sufficient pressure, the well gas may be used.

Rodless pumping equipment continues to receive extensive study. Several new designs are being tested at various places in the state. The plunger-lift and hydraulic types have given successful performance on many operations and additional installations of these units are being made in the deeper wells. The deepest well now being pumped with the plunger-lift is in Kettleman Hills and is being produced through 4-in. tubing from a total depth of 8204 ft. The deepest well being produced by hydraulic pump, also at Kettleman Hills, is pumping from 8600 ft.

The multi-stage centrifugal pump direct-connected to an electric motor by and suspended on the discharge tubing has not yet been used in California although an installation will soon be made in a Signal Hill well. At the present time a motor for this type pump is being developed for installation in a Kettleman Hills well in which high temperature is encountered.

About a year ago multiple-well pumping employing hydraulic pumps was first adopted in the Dominguez field. Since that time numerous similar installations have been made in other fields and a second one at Dominguez. Of particular interest is the very recent development in which "dry" oil from an existing dehydration plant is used as the fluid actuating the pumps, thus eliminating the need for a separate treating plant. The power station supplying high-pressure fluid to the pumps can be installed either at the dehydrating plant or at some more convenient place. When the clean oil is taken from the dehydrating station it has been found necessary to heat it by a steam jacket or heater in order to keep the lines free of wax. The macaroni strings in the wells are dewaxed every five or six months in the Dominguez installations.

One of these "gang" pumps is serving nine wells. The well depths range from 4400 ft. to 5100 ft. and the distances from the power station vary from 50 to 2600 ft. The main power-oil line is $2\frac{1}{2}$ in. in diameter; $1\frac{1}{2}$-in. branch lines extend to the wells. The amount of oil necessary for the proper operating speed of each pump is controlled by a needle valve placed on the line into the well. Any number of wells can, of course, be pumped from the one power station within the capacity of the triplex pumps that pump the power oil.

When multiple-pumping was first used, a treating chemical was introduced into the intake of the triplex pump. This mixed with the previously cleaned power oil and with it was pumped down the hole where it treated the crude oil being produced. It has been found, however, that a more efficient job of treating the oil is done if the chemical is injected into the casing of the well. The produced oil plus the power oil is metered continuously at the surface and then enters the production line through which it is transported to the tanks. The power oil into each well is metered at regular intervals, usually once a week, and from the ratio of power oil to total oil taken from the well during the metering period, a close estimate for the intervening days is obtained.

Multiple-Zone Production

Although production from more than one zone by one well is being practiced in a number of fields in California, the greatest interest still centers on the practices developed in the Wilmington field, especially in the Long Beach Harbor district. Production packers have become important equipment under these conditions; the importance has stimulated improved designs to meet the requirements for flowing oil from two or three zones, keeping the production from each zone separate.

When completing a well to produce from two segregated zones, the liner is run and cemented between the two sands. The annular space between liner and tubing is packed-off at some point between the perforated sections of liner opposite each of the two zones. Oil entering the well from the lower zone is produced through the tubing; oil from the upper zone is produced through the liner.

Segregated production from three zones is, in general, obtained by cementing blank sections of the liner between the top and middle zones and between the middle and bottom zones. In the Wilmington field it is also frequently necessary to cement between two sand strata in the middle zone to shut-off intermediate water occasionally found; a total of three cement jobs for four producing horizons. The two sands of the middle zone are not, however, separated in production.

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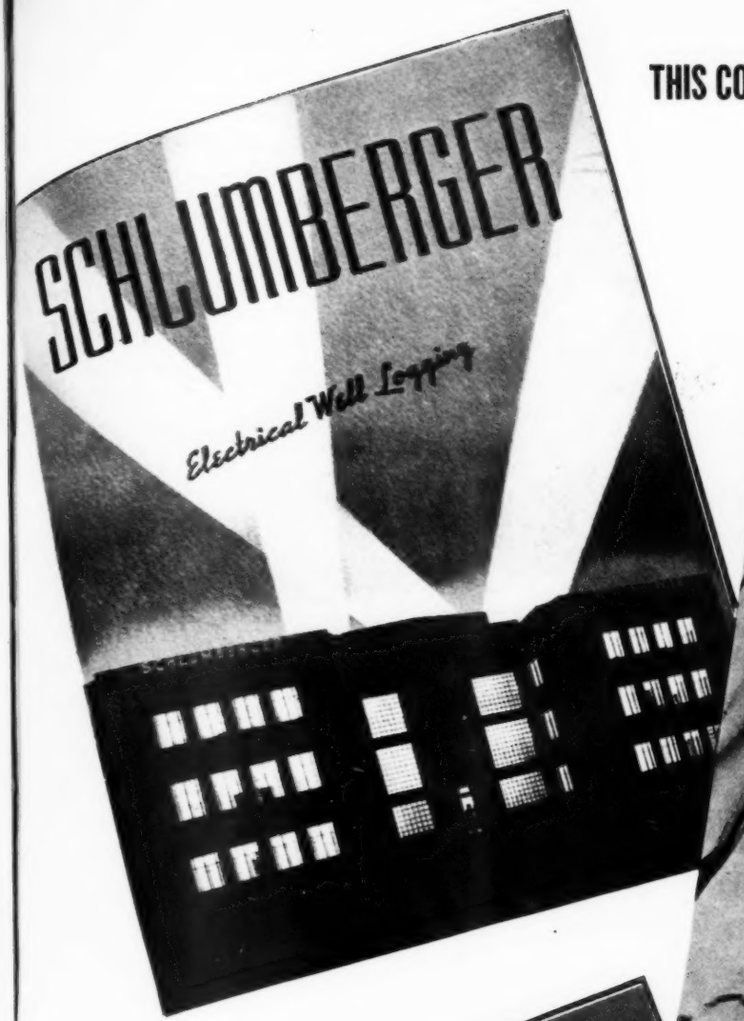


After the liner, usually 8⅝ in., is cemented, a 6⅝-in. flow string is run into the well and a packer is set in the annular space between the 6⅝-in. and 8⅝-in. strings below the perforations opposite the top productive zone. Tubing is then run through and below the bottom of the flow string; the annular space between the tubing and the 8⅝-in. liner is packed off at some point in the blank section between the middle and bottom production perforations.

The well is then connected-up so that oil from the lowest zone is produced through the tubing; oil from the middle zone (whether from one or two horizons) is produced through the annular space between the tubing and the 6⅝-in. flow string, and oil from the top zone is produced from the space between the flow string and the liner. Variations of the method have been developed and different types of production packers have been used.

Drillable metal is now being employed widely as liners and in the construction of the metal parts of the packers. Drillable metal is being used for liners and sections of the liner strings for various purposes. Its greatest use is probably as regular production liners or screens. When used as top sections of steel liners it provides a readily drilled window for deepening operations or repair work. A recent development in repair work is the use of the drillable material as pipe sheaths, sometimes called "scabs," placed inside older liners or casing strings as reinforcement. The greatest advantage of the drillable material is, of course, the ease with which it may be drilled-up and circulated out of the hole.

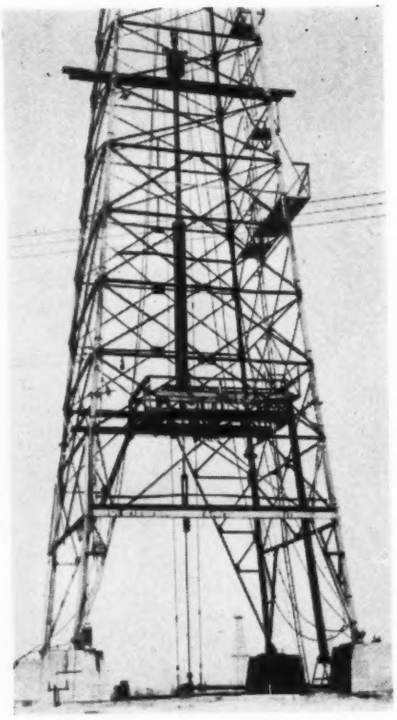
Subsurface Conditions

Sand conditions in the Wilmington area have caused considerable trouble. Although gravel-packing has eliminated this to a considerable degree, until very recently its use was confined to one sand. With the development of the liner pre-packed with gravel, described in a previous article[2], it has been found possible to pack more than one zone in a well with gravel and to cement between the gravel-packed sections of liner.

During the last two months this method has been used in a number of wells producing from two or three zones. The results have made some engineers consider the pre-packed liner one of the most important advances in production practices during the last year. It is believed that uniform packing of the gravel at the surface is more effective and dependable than when the gravel is put in around the liner after the pipe has been run into the hole. The thickness of pack used to date is 1 in. but it is believed that even this relatively thin sheath of gravel might be decreased with advantage. Any influence toward greater production by increased size of hole is, of course, minimized by use of the thin pack that requires only a slight hole-enlargement below the water string; however, there seems to have been little consideration of large-hole advantages in any gravel-pack operation yet conducted in California.

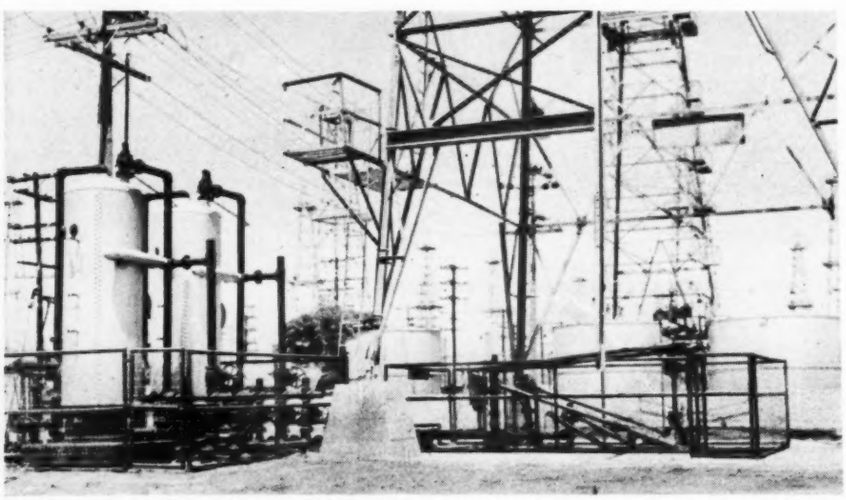
The study of bottom-hole pressures has steadily advanced during the last year. Many companies with holdings of any size on which a number of wells are being pumped are taking systematic readings either of bottom-hole pressure or of fluid levels. These data contribute to increased efficiency of operation and to more accurate estimates of future performance both of individual wells and of productive areas. From bottom-hole data obtained, distribution of production and of reservoir control is regulated.

The use of the bottom-hole pressure bomb requires the pulling of rods and sometimes the tubing. This interferes with production because of excessive down-time. Devices now available for measuring the fluid level in the well without removing the rods or tubing or even stopping production at all have encouraged the adoption of fluid level measurement at frequent intervals as a more general practice. This has not entirely eliminated the desirability of taking bottom-hole pressure measurements using bombs or gauges but it has made it feasible to run the bottom-hole pressure-bomb less frequently. From the fluid level determination the static pressure can be ascertained; although bottom-hole pressure determinations are probably the most accurate basis for establishing proper production control, fluid-level measurements have contributed much to production control by providing a more frequent check-up of subsurface conditions.

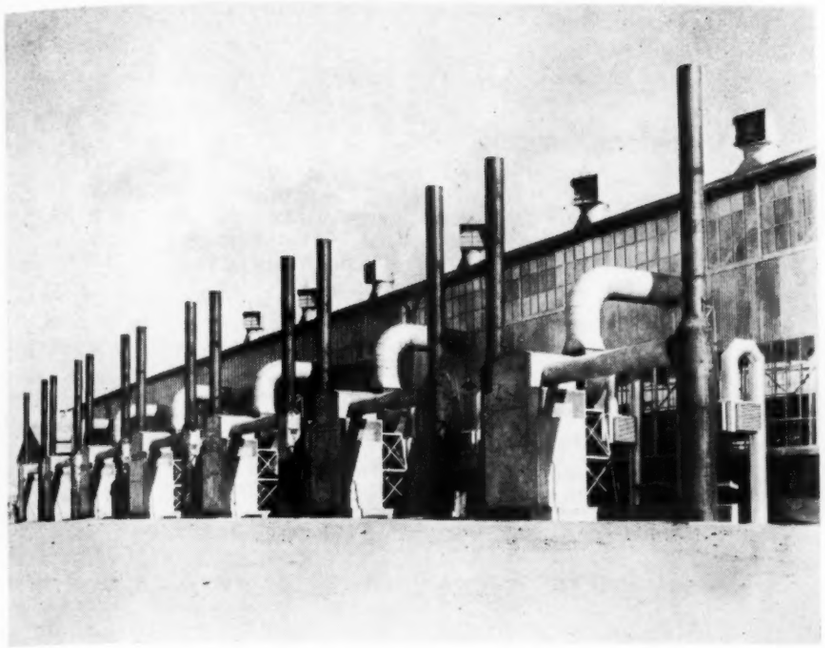


Well pumped by rods actuated by a pneumatic pumphead

[2] "Perforated Liner is Gravel-Packed Before Being Placed in Well," by Wallace A. Sawdon, *The Petroleum Engineer*, April, 1939.



Typical hook-up for producing oil from three segregated zones



An example of modern trends in compressor station muffler design

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

By

ROY W. PARKER

Oklahoma Natural Gas Company

Recent Progress in Natural Gas Transportation

THE past year has been marked by the continued progress and expansion of the natural gas industry. The expansion of the industry is indicated by the increase in volume of gas transported to a 1939 figure 25 percent more than that of ten years ago. A map of the United States depicting the present existing gas carriers shows that virtually every section is now served, except the New England States, a portion of the Eastern Seaboard, and the Pacific Northwest. Expansion has continued until present statistics indicate that a total of two and one-half trillion cu. ft. of natural gas was consumed the last year. This volume was distributed to approximately 7,150,000 consumers and the estimated revenue was about $420,000,000. This is a slight decrease from the figures for the preceding year despite the fact that expansion programs completed during the year and additional sales efforts to increase domestic use in established territories have virtually compensated for the loss in volume resulting from decreased industrial consumption, which is conservatively estimated at 15 percent. The first quarter of 1939, however, shows a definite upturn in all phases of the gas industry's activities. Preliminary estimates for the first three months of 1939 indicate that domestic sales gained 12 percent, industrial sales 6 percent, and commercial sales 12 percent over the respective sales in the similar period of 1938.

ROY W. PARKER

has been in the employ of the Oklahoma Natural Gas Company for 13 years, one year having been spent in the measurement department, one year in the meter repair department, four years as assistant chemist, four years as chief chemist, and the last three years as industrial sales engineer—Prior to his affiliation with Oklahoma Natural he had been employed in the refining department of The Texas Company, from 1923 to 1926 — He is a graduate of Southeastern State College.

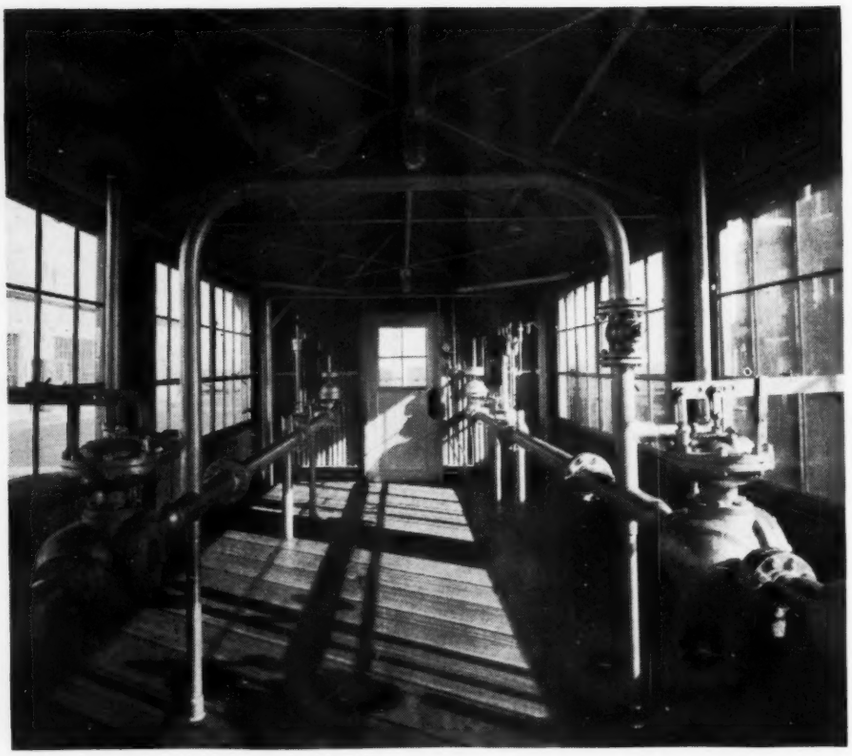
Many distributing companies are increasing their facilities to serve additional territories as well as to supply increased demands on their present systems. Although no major project has extended the boundaries of natural gas service the last year there has been a concentrated effort on the part of many companies to make line extensions to existing and potential markets within the areas served. New fields have been discovered and proven fields more fully developed to assure an adequate supply of gas and increase the flexibility of present systems.

It has been a comparatively quiet year even though most major gas companies have either projected, started construction of, or completed additional pipe line facilities. A summary of some of those reported includes:

New Line Construction

The Mountain Fuel Supply Company constructed 53 miles of 18-in. loop line in Wyoming and Utah. The project involved laying pipe from Bigelow Hill, Wyoming, to Coalville, Utah. This was one of the largest projects of the year and was built during extremely adverse weather conditions.

The United Gas Pipe Line Company built a 47-mi. line to Houston, Texas.



Fuel regulator station at Haven, Kansas, compressor station of Panhandle Eastern Pipe Line Company

The new line is from the Katy field and is constructed of 8-in., 10-in., 12-in., and 16-in. pipe. The line is welded except the 16-in., which is coupled. The average working pressure on the line is 350 lb. per sq. in.

Oklahoma Natural Gas Company laid 15 mi. of 12-in. pipe line from the Cement field in Caddo County, Oklahoma. This line ties-in to its present system near Chickasha, Oklahoma. Welded lengths of 200 ft. were coupled in constructing this line.

Lone Star Gas Company completed the construction of 18 mi. of 18-in. line from Buffalo field, Texas. This line is connected to the company's 12-in. line from the Long Lake field, Texas.

Houston Pipe Line Company laid 12 mi. of line from Spanish Camp field, Texas.

The Southwest General Pipe Line Company, Dallas, Texas, constructed 21 mi. of 6-in. trunk line from Tomball field, Texas, to connect with the Southern Union Utilities line.

The Northern Natural Gas Company added to its system by laying 40 mi. of 16 in. from Ventura, Iowa, to Albert Lea, Minnesota. The line is designed for 400-lb. working pressure.

The Carnegie Natural Gas Company completed an 8-in. line, 27 mi. in length from the Chestnut Ridge area, Pennsylvania.

Arkansas Louisiana Gas Company constructed 18 mi. of 6-in. from Schuler field, Arkansas.

Many other companies such as the Central Gas Utilities Company in Kansas, Beaumont Natural Gas Company, and others have reported extensions and replacements in their present systems.

It is apparent that gas companies in all sections of the country are expanding their individual systems. The larger state-to-state carriers are at present planning to project lines that will further change the boundaries of the industry's business during the coming year.

Problems Are Studied

Progress in natural gas transmission the last year has not developed revolutionary methods of construction or operation. In construction practice more consideration is being given to features in the completed system that will contribute to greater efficiency and economy of operation. The crucial tests of transmission do not begin until construction has been completed; hence successful operation of the completed project is largely dependent upon original engineering decisions concerning design and practical methods of carrying them out. There has continued the last year a definite trend toward increased application of engineering and technology; construction and maintenance practices have improved and the manufacturers of materials and equipment have kept pace with construction progress. To this end the pipe manufacturers have developed pipe that is designed for 1500-lb. pressure and that is actually operating at a pressure of 1300 lb. Operation at such high pressure will permit a system to transport 15 to 20 percent more volume than at pressures formerly considered "high"—a pronounced economic gain in gas transmission. The saving is particularly important in long distance lines inasmuch as a given volume can be transported through smaller and, therefore, less expensive pipe. Welding practices[1] and the results from various methods are constantly being studied. Generally speaking, pipe having a longitudinal butt-weld is not being used for high-pressure operations. The failures in obtaining a 100 percent weld render this type of fabrication unreliable under extreme working conditions. Lap-welded pipe because of its greater contact area is more nearly uniform but often scale or gas-pockets reduce the possibility of a perfect job. Because of the processing method seamless pipe is more likely to be uniform.

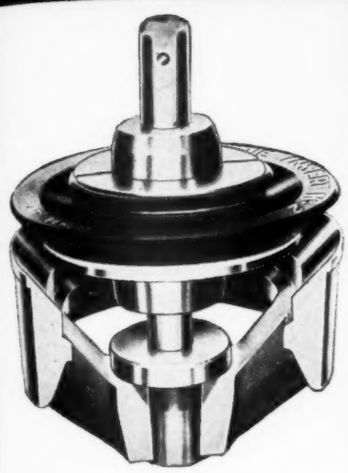
The problem of metal durability exists in other materials used in line construction, including gate valves, pumps, gas engines, and all auxiliary fittings. The trend toward obtaining longer life has been to reduce the carbon content in cast-iron for valve metals and to obtain, thereby, a finer-grain metal often referred to as semi-steel. This product resists more effectively corrosion, erosion, oxidation, shock, and strain.

The quality of the physical materials incorporated in any gas system will undoubtedly affect the extent to which continuous, uninterrupted service is obtained. There are other problems, however, to be considered before this assurance is a reality. These transmission problems have received much consideration and thought during the year and the solution is nearer. Reference is made to internal stoppage either in the transmission line or in the appliances in which the gas is utilized. Reduced pipe-line capacity and often complete stoppage have resulted from the freezing of gas hydrates[2]. The behavior of hydrates when the temperature is above 32°F. has been studied for some time and curative measures are being developed as experimentation progresses. Several companies have installed dehydrating plants on their transmission lines to correct this condition but in some instances the cost

[1] "Metals Used in Pipe Line Construction and Operation," by Lewis F. Scherer, *The Petroleum Engineer*, Sept. and Oct., 1938.

[2] "Preventing and Removing Hydrates in Natural Gas Pipe Lines," by E. G. Hammerschmidt, *Gas Age*, Apr. 27, 1939.

Insure YOUR PUMPS AGAINST BROKEN RODS *and* WASHOUTS....



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LAST 100% LONGER because of the Mission principle of ***"Pull the bushing and save the seat."***

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Valve seat is made of drop forged, heat treated alloy steel especially selected for **strength and toughness.**

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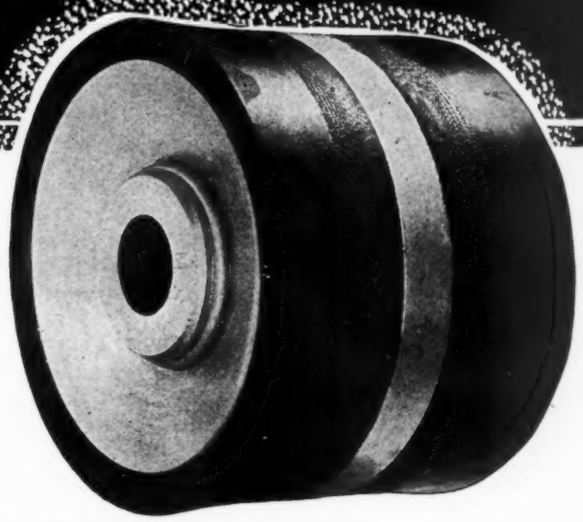
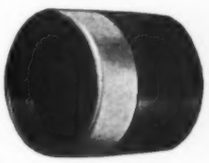
Long wearing rubber valve inserts. The rubbers are **easy to change** due to unique cap and spring.



MISSION PISTONS **protect your pump from damage due to broken rods,** and eliminate washouts between piston and rod... because of... forged steel bodies which permit the use of tapered rods—the strongest and most fluid-tight known.

MISSION RODS have a **File Hard Case** on a **Super Strength Core** which has a minimum tensile strength of 120,000 lbs. per sq. in., which is 50% stronger than typical hardened rod.

MISSION Self-Sealing GLAND PACKINGS:



Positive seal is secured from fluid pressure, preventing cutting of rod from leaking fluid. Under pressure **only** when seal is needed, greatly prolonging the life of rod and packing.

PUMP INSURANCE . . . FREE

MISSION UNCONDITIONALLY GUARANTEES to repair at no cost to user, any damage to pumps caused by breakage of Mission Rods when used in conjunction with Mission Pistons and Mission Self-Sealing Gland Packings.

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INSURES LOWEST POSSIBLE PUMP UPKEEP COSTS AS PROVEN BY UNSURPASSED RECORDS THROUGHOUT THE WORLD

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of such a plant is not considered justified. Anti-freeze compounds are being added to the gas stream in some lines to prevent formation of hydrate-ice. Various compounds have been used, such as ammonia, methanol, ethanol, calcium chloride, and acetone.

Foreign matter in the gas is another cause of retarded delivery or interrupted service that is receiving more attention. The introduction of the latest appliances has required that gas used in them be free of foreign matter to avoid trouble. Modern appliances, especially ranges, are automatic in operation and require one or more pilot lights. Even a very minute quantity of dirt will often cause stoppage in these small orifices. Stringent requirements of this kind have necessitated that gas scrubbers receive more attention than formerly.

A method of removing corrosion products or foreign matter from the line is receiving considerable attention at present. The industry has borrowed the "go-devil" idea from oil pipe line practice and a specially designed scraper for use in gas lines is being used. It is reported that flow capacities have been increased as much as 20 percent after this operation.

Improvements have been made in almost all phases of gas pipe-line construction, operation, and maintenance. New problems have arisen and practicable methods have been applied in their solution. Economy has continued to be a major consideration in planning new projects but not to the point of jeopardizing the possibility of long-time continuous service.

Largest Gas Well in History

Though new markets have been connected during the last year it has not been necessary to erect many entirely new booster stations. The increased pressure and supply necessary for the delivery of greater volume were obtained in most instances from reserve well pressures in fields in which high rock pressures and greater open flows existed. For example, in 1938, deeper drilling in the Cement Field[3], Caddo County, Oklahoma, resulted in the discovery of the largest dry gas well ever tested in the history of the industry. The Magnolia Petroleum Company's Niles No. 10 had an initial open flow of 224,000,000 cu. ft. per day with a rock pressure of 1650 lb. per sq. in. The potential has increased and now the open flow is 640,000,000 cu. ft. as measured by the U. S. Bureau of Mines back-pressure method. The Oklahoma Natural Gas Company's Hedlund No. 1 tested 161,700,000 cu. ft. per day at a rock pressure of 2025 lb. per sq. in. These wells are approximately 4200 ft. deep and several, being drilled to a depth of 5000 ft. and greater, are showing good results, which presage a trend to deeper drilling in areas where shallow sands have been exhausted. A well in the Chickasha field, Oklahoma, long a source of much of the gas consumed within the state of Oklahoma, and producing from several zones to a depth of 2500 ft., was recently deepened to 5400 ft. to obtain an open flow of 20,000,000 cu. ft. per day. Originally this well was to be drilled to a depth of 10,000 ft., another indication of the trend in gas-well drilling practice, particularly in seemingly depleted fields. The 5400-ft. sand in the above-mentioned well has not been definitely identified.

[3] "Natural Gas in Oklahoma," by Frank B. Long, *Gas Age*, Apr. 27, 1939.

Compressor Stations

In the course of expansion during the last year, however, several gas companies found it necessary to install booster stations to meet adequately their peak demands. The Northern Natural Gas Company constructed two new stations. One, at Oakland, Iowa, comprises two 900-hp., twin-tandem, double-acting compressor units operating at 150 r.p.m. Auxiliary equipment includes two 150-hp. units for electric power generation. The station is designed to compress 90,000,000 cu. ft. of gas per day. The other station, at Ventura, Iowa, includes three 800-hp. compressors and auxiliary units for electric power generation. These additions increase the total installed horsepower of the Northern Natural system to 37,800 and were necessitated by increased demands in Minnesota.

The Memphis Natural Gas Company has added two 600-hp., 6-cycle, angle-type compressors in its Guthrie, Louisiana, booster station. The station previously contained four twin-tandem, 1250-hp. units. The new units, added because of increased demands, give the station more flexibility as well as increased capacity.

The Southern Natural Gas Company has enlarged the capacity of one station and has constructed five new stations. One of the new stations is at Birmingham, Alabama, and comprises three 1000-hp., twin-tandem, double-acting, gas-engine-driven compressors. At Perryville, Louisiana, two 1300-hp. units and auxiliary equipment were installed. In the Onward, Mississippi, station one 1300-hp. compressor was installed, and at the Louisville, Mississippi, station two new 1300-hp. units were added. Two new stations were completed recently. One is on the Southern Natural's branch line between Marion and Selma, Alabama. The other station is at Ben Hill, Georgia. The station on the Marion-Selma line is equipped with two 400-hp., 2-cycle, gas-engine units, driving integral angle-type compressors. Each unit has a capacity of about 15,000,000 cu. ft. per day. The station includes auxiliary units, buildings, dwellings, and miscellaneous equipment. The station at Ben Hill, Georgia, has one 600-hp., 2-cycle, angle-type compressor. This unit has a

Air compressors in compressor station at Haven, Kansas

IS IT POSSIBLE?

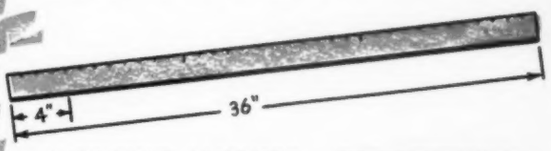
THE FIRST OF A SERIES OF "HARD TO BELIEVE" BUT TRUE FACTS CONCERNING MANY INTERESTING THINGS, INCLUDING THE BAKER LINE OF "PRACTICAL & DEPENDABLE" OIL TOOLS

THAT SOME HARMLESS LAND CRABS ONCE CAUSED AN ARMY TO FLEE IN TERROR?

AND THE ANSWER:

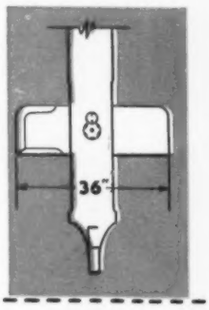
In 1635 Admiral Penn landed with his forces on the island of Haiti to establish a colony. Surprise attacks by natives had set the nerves of the expedition on edge. One night the camp was awakened by the clattering on the beach of what seemed like hoofbeats of charging cavalry (but what was in reality the noise made on the hard sands of the beach by a large number of mammoth land crabs). The expedition fled in terror, leaving behind an amazed populace, and the legend of the bloodless "Battle of Crabs."

THAT THERE IS AN OIL TOOL THAT WILL ENLARGE THE DIAMETER OF AN OPEN HOLE FROM 4" TO 36"?

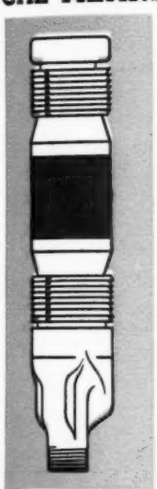


AND THE ANSWER:

The Baker Rotary Wall Scraper has been so designed as to provide tremendous strength with minimum over-all dimensions and an amazing reaming capacity. It has a reaming range of from 4" to 36", using only six Wall Scraper Bodies. For complete details, send for Baker Broadcast No. 19.



THAT GAS/OIL RATIO IN AN OIL WELL HAS BEEN REDUCED BY MECHANICAL MEANS FROM 26,300:1 TO 366:1?



AND THE ANSWER:

Some remarkable records have been established in reducing gas/oil ratios as the result of cement squeeze jobs done with the Baker Cement Retainer. In a typical instance, a well was brought in making 105 bbls. of 29° oil with a gas/oil ratio of 26,300:1. A cement squeeze job was done with the Baker Cement Retainer, and the well came in with production of 612 bbls. of oil with a gas/oil ratio of 366:1.

Full details are given in Baker Broadcast No. 17-A—send for it.

THAT THERE IS A COUNTRY IN THE WORLD WHERE IT IS MANDATORY THAT A CRIMINAL ADVERTISE HIS CRIME?

AND THE ANSWER:

In a certain South American tribe of Indians, if a member commits homicide, he must leave his calling card beside the body of the deceased. This calling card is in the form of an animal bone, half of which is placed beside the victim, and the other half must be worn around the neck of the perpetrator of the crime. When the victim is found, the eldest brother of the deceased must search for the tribesman that has the matching half of this bone around his neck, and vindicate the stain upon the family honor.

THAT ONE OF THE MOST DECISIVE NAVAL BATTLES OF THE WORLD WAR TOOK PLACE IN THE HEART OF AFRICA?

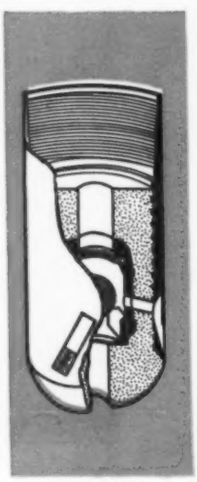
AND THE ANSWER:

Yes, it actually happened. In 1915 Belgian military operations on Lake Tanganyaka, Central Africa, were being seriously hampered by a German "flotilla" consisting of four gunboats. The British Admiralty organized the African Naval Expedition consisting of 28 picked men and two 40-foot motor boats, each mounted with a three-pounder forward.

After months of strenuous travel, through jungles and mountain territory—always dragging, pushing, guarding their precious "navy," the Expedition finally reached their destination.

The rest of the story is written in the history of British naval victories. One by one the German gunboats were encountered and sunk. Thus ended the smallest expedition sent against the enemy during the World War, one of the most decisive, and one of the most courageous.

THAT THERE IS A SHOE USED IN LANDING AND CEMENTING OIL WELL CASING THAT WILL: EFFICIENTLY GUIDE; SAFELY FLOAT; ASSIST IN WASHING OUT BRIDGES ENCOUNTERED; SCOUR WALLS OF THE HOLE; PROVIDE ULTIMATE IN CEMENTING EFFICIENCY; AFFORD POSITIVE BACK-PRESSURE VALVE; THAT IS COMPLETELY DRILLABLE, AND LEAVES THE HOLE IN PROPER CONDITION?



AND THE ANSWER:

The Baker Cement Wash-Down Whirler Float Shoe will do all of these things safely, efficiently and economically. For complete details see page 229 of your 1939 Composite Catalog, or send for individual Baker Catalog.

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A small booster station nearing completion

capacity of 20,000,000 cu. ft. per day. The auxiliary equipment is similar to that at the other stations. These stations will operate only when peak demands occur on the company's main line serving this territory.

The West Texas Gas Company found it necessary to add compressor facilities to its main transmission system that serves 42 towns in Texas. This new station, constructed in 1938, is about 30 miles northeast of Amarillo. The main compressor equipment consists of three 250-hp. 2-cycle, gas-engine-driven units.

Lone Star Gas Company constructed a station at Shamrock, Texas. The pressure in the Panhandle field has declined more or less steadily during the last several years. The station, built to boost this declining pressure, consists of nine 160-hp. units and six 170-hp. units. The 170-hp. compressors were transferred from another gas field that had been depleted.

The Phillips Petroleum Company[4], operating in the Edmond field, Oklahoma, produces large quantities of gas with oil. Much of the gas is used as fuel and for other operating purposes but the surplus is transported and sold. To move the gas, a large compressor station was erected by the company in the center of the pool. The gas is compressed in three stages by twenty-seven 250-hp., twin-cylinder, horizontal compressors having inverted exhausts. All-steel building construction and an ample number of doors, windows, and roof ventilators reduce the fire hazard to a minimum.

Canadian Western Natural Gas, Light, Heat and Power Company[5] is supplied with gas from the Turner Valley field by the Royalite Oil Company, Ltd. Pressure difficulties in the distribution system prompted the latter company to design and construct a compressor station in the field. V-angle type, 600-hp., 2-cycle units were selected for this station. The pressure is boosted from 250 to 325 lb. per sq. in. and the rated capacity of each compressor is 27,000,000 cu. ft. per day. Equipment includes silencers, hydraulic governors, and magnetos. The building and headers at the Turner Valley plant are constructed so that extensions and additions can easily be made.

[4] "Modern 6750 hp. Compressor Station Aids Gas Conservation," by J. C. Albright, *The Petroleum Engineer*, Feb., 1938.

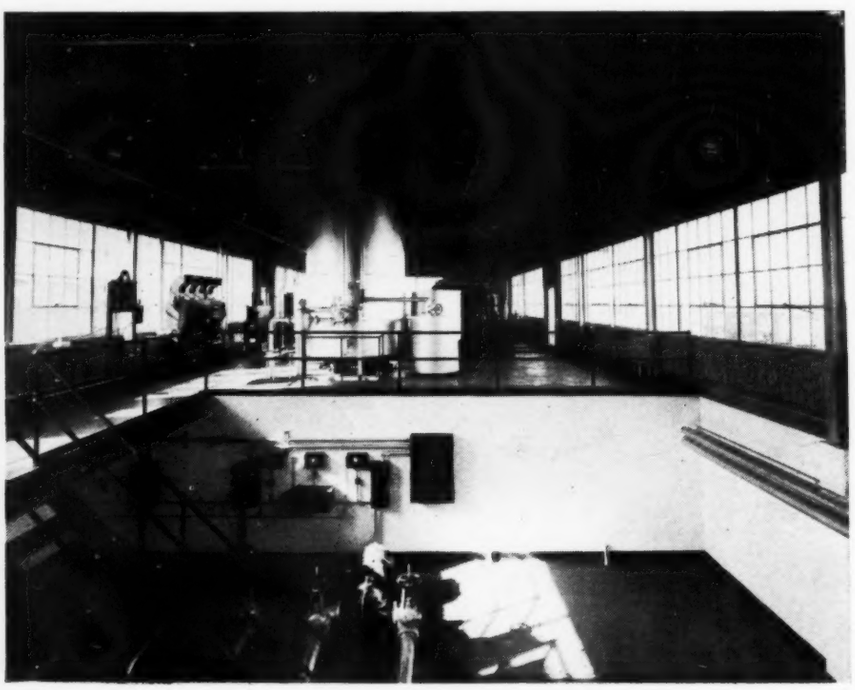
[5] "Compressor Station Design Facilitates Installation of Additional Units to Increase Capacity," by Frank H. Love, *The Petroleum Engineer*, May, 1939.

Station Designs Are Changing

The basic principles of operation and design of compressor stations have undergone some changes in recent months. The manufacturer in continuation of his efforts to improve and perfect the accepted prime mover is constantly searching for new engineering ideas that might improve the efficiency of transmission. There seems to be a definite trend to certain types of equipment and station designs are being given more consideration than usual. A review[6] reveals that to 1923 the main compressor units were compressors driven by a long belt and a "stationary engine." This type was displaced by direct-connected engines and compressors. These units afforded the advantages of compactness, freedom from belt trouble, and a much wider choice of sizes and horsepower. For these reasons they were readily accepted. During this same period several improvements were made in the design of the 2-cycle power cylinder. The fuel injector was perfected, cylinder and piston cooling was improved, and scavenging air pressure and power was reduced about 30 percent as effectiveness was increased.

More recently a third type has been developed and is now being manufactured. This type, the vertical-angle, is proving very popular and many of the newer stations are being equipped with

[6] *Design and Operation of Compressor Plants*, by T. Hume West, Gulf Publishing Company, 1939.



Pump pit at modern compressor station. Note automatic switch box on wall for starting and stopping the pumps

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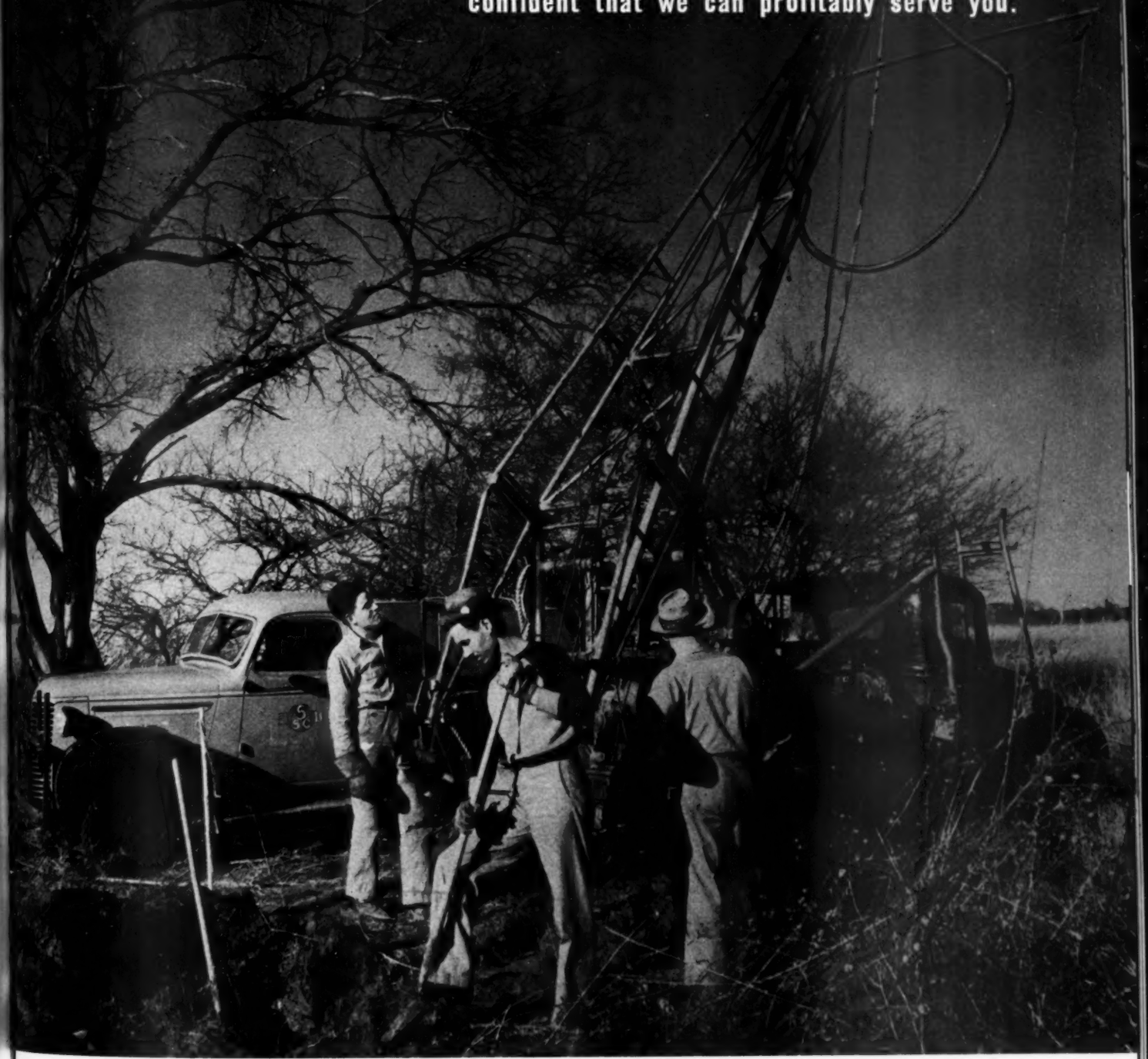
One hundred crew-years of experience gained in many countries have resulted in our discovery of more than 49 NEW producing oil fields. Our service is complete and efficient. We are confident that we can profitably serve you.



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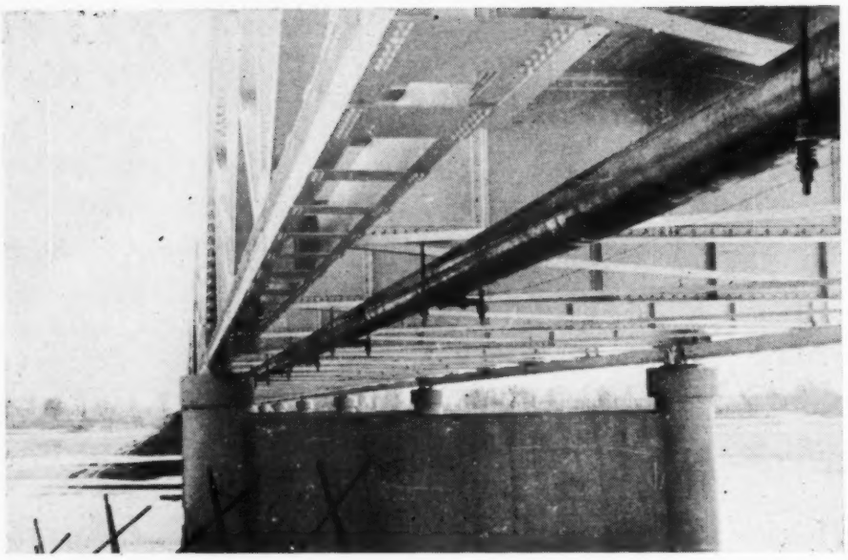


Oklahoma Natural Gas Company's gas line suspended under the new Arkansas River bridge near Bixby, Oklahoma, an example of the trend in modern practices in pipe-line construction

them. These units afford the advantage of still greater compactness, lighter weight, lower cost, and greater economy in plant design. Because of changes in the design of several prime movers further thought and study of the plant piping arrangements have been necessitated. Average gas velocities are usually used when designing a plant and the inlet and outlet piping arrangement has a decided effect on economic operation. For that reason considerable research is now being made in the field of plant piping especially where pulsating flow might exist. Reciprocating units generally used in plants are prone to cause pulsating flows in the lines. Research work by several engineers is now being conducted and valuable flow data, which no doubt will help to correct this pulsation, should be available soon.

Auxiliary equipment has received its share of engineering attention and now modernized units are available. Not so long ago this equipment usually was a maze of belts, shafts, pulleys, and guard-rails. Compact, self-contained units are now available that require little space, are much safer to operate, and present a neater appearance. Miscellaneous station equipment, such as water pumps, cooling towers, mufflers, piping, etc., have received their share of attention and consequently have been modernized and made more efficient.

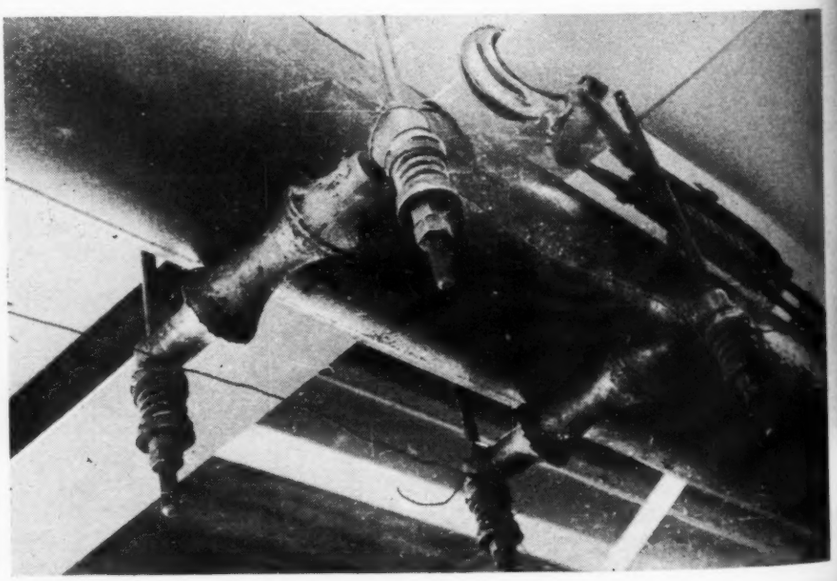
Operation and maintenance of compressor stations has followed the general trend of economy and efficiency. More attention is being directed toward engine performance. Instruments now being adopted widely in compressor stations are the neon timing indicators and exhaust gas analyzers. The first assures exact timing and the latter, proper mixture of fuel-gas and air. Load control using variable clearances is receiving more attention. This permits a wider range of intake and discharge pressures. A magnetic device for testing metals for hidden fractures is a step toward safer operation and reduced maintenance cost. There is a definite trend toward additional automatic controls. Thermostats operating in conjunction with timing devices are being used more generally to start and stop pumps, air compressors, etc.

In the design and construction of new compressor stations more and more attention is being given to the health and comfort of the personnel. New compressor stations[7] in the "dust bowl" are now equipped for air-conditioning. The method usually employed is to wash and clean all air entering the engine room and to maintain a pressure within the room slightly higher than atmospheric by sealing all cracks and openings in the building. This prevents the infiltration of dust-laden air and provides a dust-free atmosphere better for the operators and the station equipment alike. Attendants' homes are also air-conditioned. At the rear of these dwellings a forced-air filter has been installed that cleans and distributes fresh air throughout the several rooms.

Some stations[8] utilize the waste heat from the engines to heat the station during the winter months. Air heated by contact with engine exhausts is carried to various parts of the compressor room by a special circulator unit and system of ducts. Industrial-type unit heaters are used only when engines are down. One compressor building, 80 ft. by 32 ft. by 12 ft., in the Quinton, Oklahoma, field is using this method and obtaining excellent results. The duct system, blowers, and motor cost $1046. Older stations that employ steam boilers for heat find it necessary to employ or retain an additional man on the station staff to operate the boilers.

[7] "New Compressor Station in 'Dust Bowl' Area Equipped for Air-Conditioning," by Frank H. Love, *The Petroleum Engineer*, Feb., 1938.

[8] "Compressor Station Heating System Utilizes Waste Heat," by J. C. Albright, *The Petroleum Engineer*, July, 1938.



The suspending arrangement used on the Bixby, Oklahoma, bridge project

Mr. Daugherty discovered the way to lower pumping costs in East Texas

OTHER operators in fields such as Mexia, Freer, Pettus and Beaumont, Texas; Seminole, Oklahoma and Smackover, Arkansas, where corrosive and sand-laden fluids must be pumped, have also found that "Oilwell" DI-HARD Barrels lower lifting costs.

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By Jno. R. Daugherty
Vice Pres. & Gen. Supt.

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DI-HARD metal has successfully resisted corrosion in the many types of well fluids in which these working barrels and plunger pumps have been used.

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Under an exclusive license, "Oilwell" manufactures for all oil fields throughout the world, except California, plunger pump barrels and working barrels lined with DI-HARD metal and plungers clad with this material.

Inside and outside view of "OILWELL" DI-HARD Working Barrel. The uniform concentric reflections indicate the perfectly smooth high polish inside surface.

OIL WELL SUPPLY COMPANY

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Preparing to record data. Note that the instruments are mounted on three litters that are moved by manpower

Developments and Trends in Geophysical Petroleum Prospecting

THE trend in geophysical petroleum exploration over the last year shows a definite shift in reconnaissance investigation from the reflection seismograph and torsion balance to the use of the gravimeter[1] and experimentation in soil and soil-gas analysis. The refraction seismograph has virtually been discontinued.

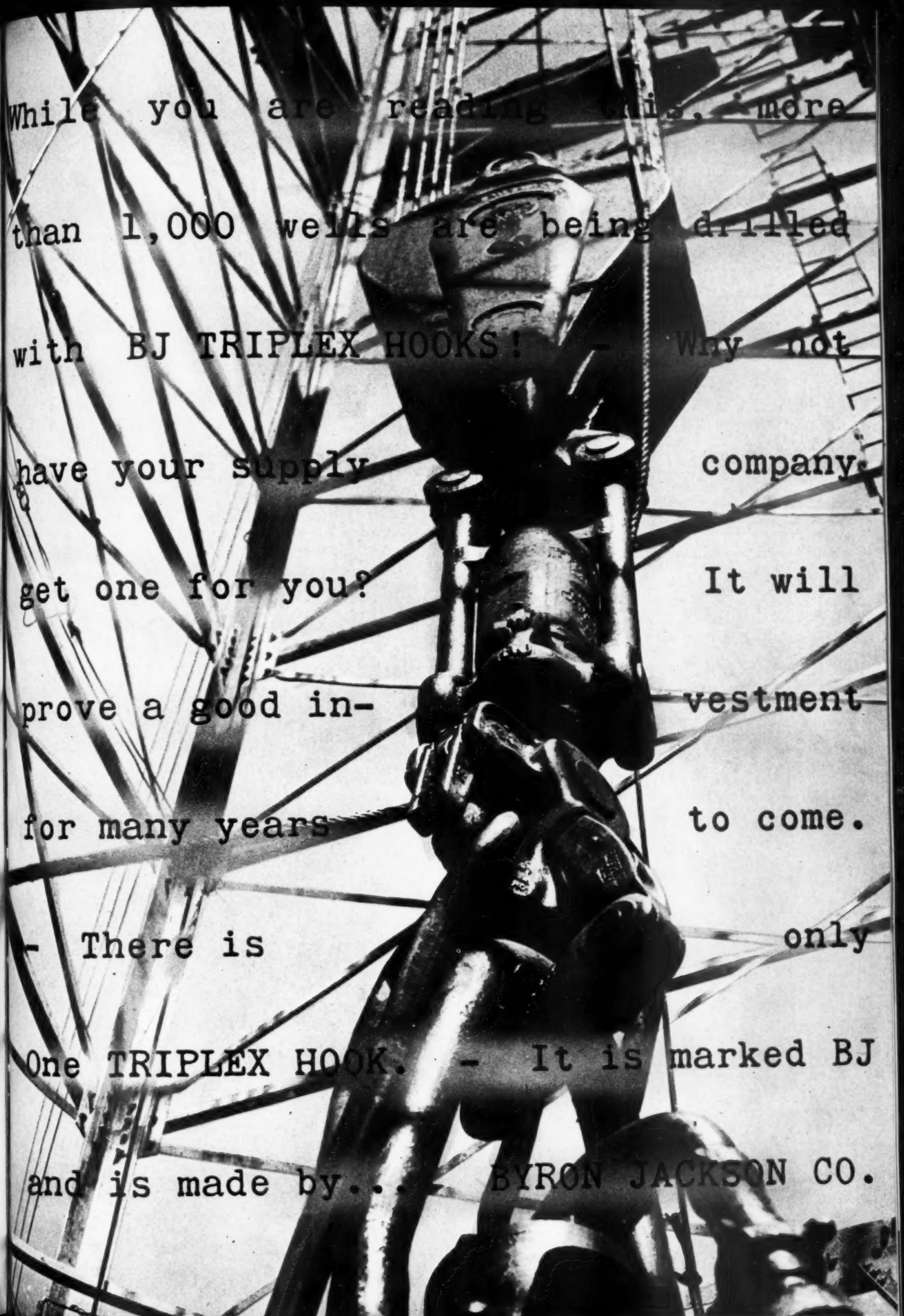
[1]The names *gravimeter* and *gravity-meter* are both in common use at present in the United States. The word *gravimeter* seems to have priority, being used by Schweydar to describe an instrument called the Schmidt Trifilar Gravimeter in 1914. The word virtually disappeared from the literature for several years thereafter. At the time the Gulf Research and Development Corporation began to experiment with this type of gravity measuring device it was decided to use the term *gravimeter* in preference to *gravity-meter* on the analogy of the term *ammeter* as an abbreviation of *ampere-meter*. This was in 1932; at the same time or shortly thereafter, Thyssen in Germany, working on another type of instrument, also used the term *gravimeter*. The latter, therefore, seems the preferred form both from the viewpoint of history and of convenience.

The reflection seismograph, however, is still in use both for reconnaissance in new areas and for detailing structural indications found by other geophysical methods. Particularly in Illinois and Indiana has reflection seismograph been used with remarkable success.

One of the most important oil-field discoveries in recent months based on reflection seismograph indications was the finding of the Eola field, Avoyelles Parish, Louisiana. Commercial production from the Wilcox sand was obtained in February, 1939, in the discovery well, Sid Richardson's Haas Investment Company No. 1, at a depth of 8550 ft. This is a structure of low relief and its discovery opened up a search for similar type structures in the upper Gulf Coast areas of both Texas and Louisiana. This strip of territory, commonly called the Sparta-Wilcox trend, is approximately 75 miles wide and extends from South Texas into the state of Mississippi.

Due to the small amount of reversal and the prevalence of faults in structures of the Eola type the dip-method of reflection shooting is unsatisfactory in looking for this type of structure and makes the use of correlations imperative. To meet these requirements of detailed exploration, several improvements in reflection instruments have been made. Among these are included improved types of automatic volume control and certain amplifier changes that have improved the quality of the results obtained.

These improvements have permitted the working of such territory as the Sparta-Wilcox trend area, which heretofore had been considered difficult to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Transporting casing for shot holes in Colombia

investigate by reflection. Among the newer areas opened to reflection seismograph work as a result of these refinements are the glacier-drift areas of Michigan and the limestone outcrops of Kentucky.

Despite the signal success of the reflection seismograph, especially in the newer oil fields, the total number of operating crews has decreased in the United States. There were operating in June, 1938, approximately 225 seismograph crews and in June, 1939, the number has been decreased to about 100 crews. This curtailment of seismograph activity is due partly to a general policy of retrenchment and partly to the fact that many operators are of the opinion that much of the older oil-bearing territory has been covered adequately by this method.

Investigations indicate a gradual replacement of torsion balances by gravimeters. There were operating in the United States in June, 1939, prob-

Tractors used in tandem to pull-out a drill that had bogged-down in Colombia

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Yours, *Dick*

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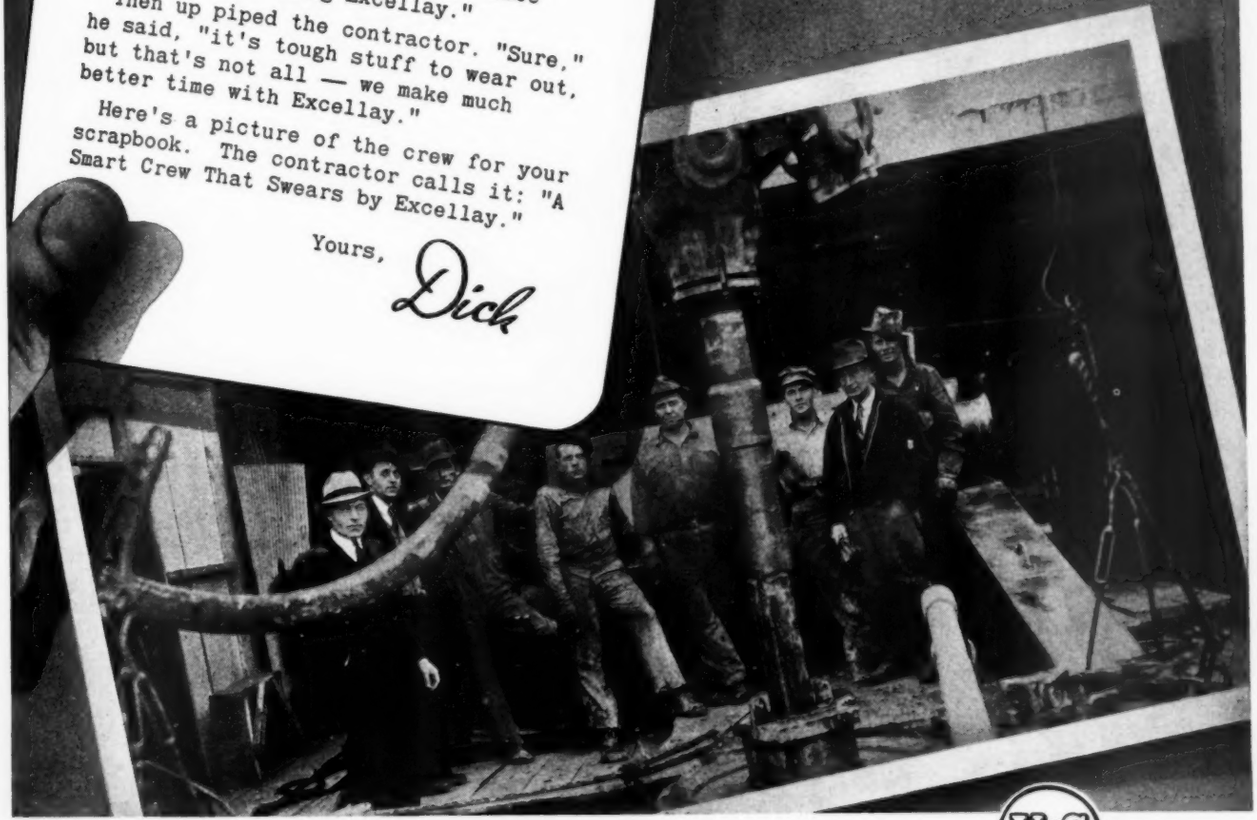

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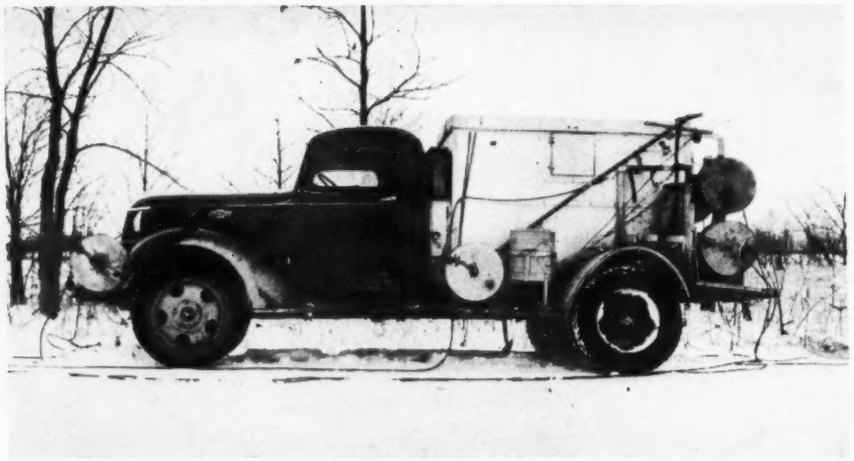

Recording truck in use in Michigan

ably not more than 15 torison-balance crews. The use of gravimeters, on the other hand, has definitely increased. Within the last 12 months the number of gravimeter parties in the United States has increased from 24 to about 60. The widespread development of gravimeter exploration is so important that a separate discussion of this method appears elsewhere in these columns.

The increasing interest in the use of chemistry in soil and soil-gas analysis also has been one of the outstanding exploration developments in the last year. A series of photographs illustrating these geochemical methods appears elsewhere in this issue.

In a tabulation of oil-field discoveries throughout the United States classified according to the method of discovery insofar as this information is available, it has been noted that in 1937, 44 oil fields were found in each of which estimated recoverable reserves exceed one million bbl. During the year 1938, 64 fields of comparable importance were discovered. It is hoped that discoveries for 1939 will be no less than the average for the last two years.

During the next 12 months geophysical exploration as a whole will probably remain close to its present level or decrease slightly, particularly in seismograph operations. There is every indication that additional gravity work, using gravimeters principally, will be authorized as new and better instruments become available. It is not believed that electrical surveying methods will do more than hold their own for the coming year.

There is no question but that soil analysis and soil-gas investigations will be subjected to further widespread experimentation and development. Many of the oil companies that have established geophysical departments are giving these methods serious consideration. Largely because of the lag between the exploration of a prospect and its subsequent drilling, it is quite possible that the coming year will not provide enough time to formulate a definite idea as to the probable success or failure of these methods. From a purely practical standpoint, it is reasonably certain that geochemistry will be given every opportunity to demonstrate its value in the coming months.

NOTE: Photographs used to illustrate this article are by courtesy of Independent Exploration Company.

Drilling shot holes with a tractor-mounted drill

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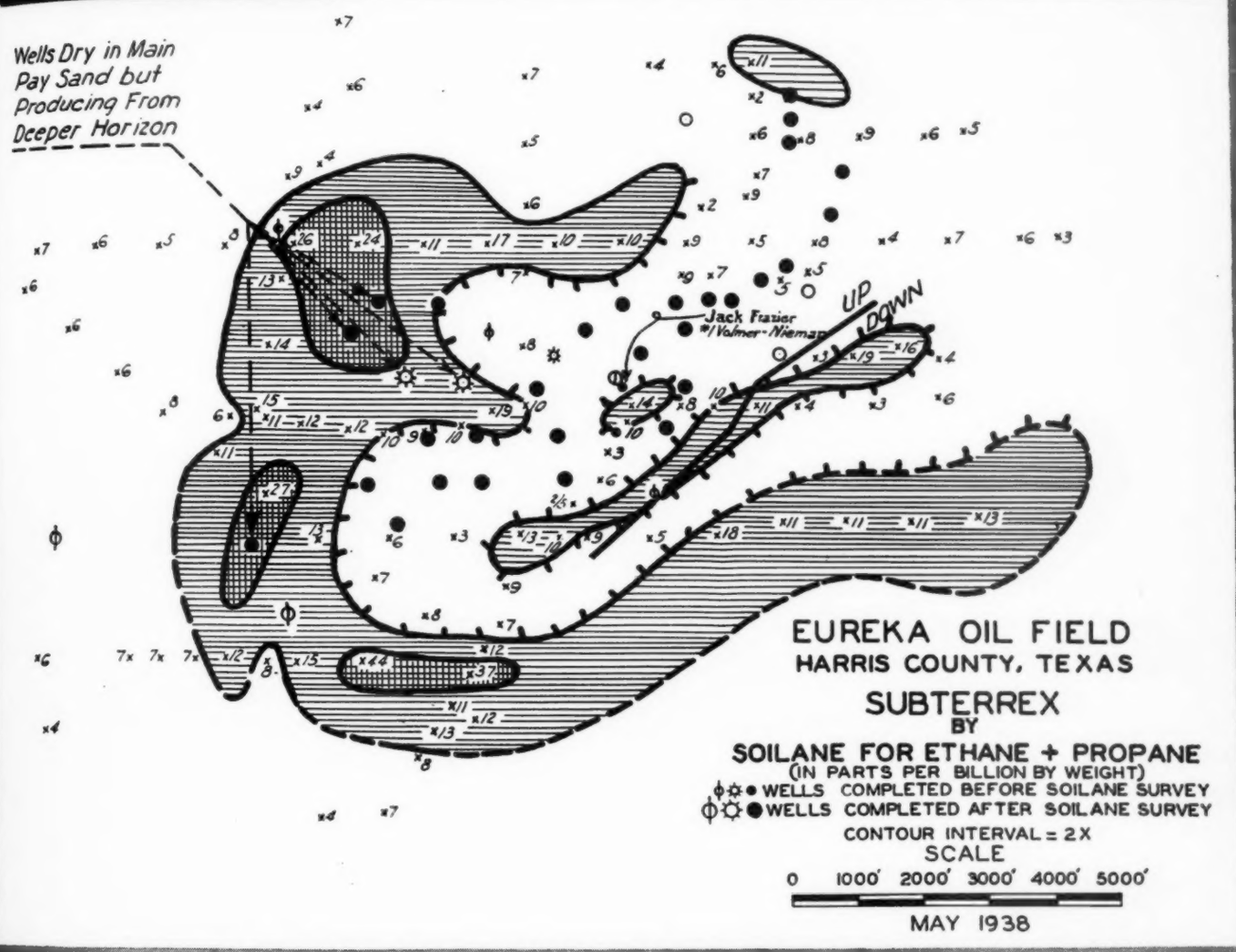

The Soilane map reproduced above was placed of record shortly after the discovery well at the Eureka Oil Field, Harris County, Texas (Jack Frazier No. 1 Volmen-Nieman), was brought in. Prior to that discovery of oil, the extent of development was three dry holes and one gas well, which last had been shut in for some time prior to Mr. Frazier's discovery of oil.

The Ethane halo, reproduced above, is shown in relationship to the subsequent development. Note how the Ethane halo predicted not only the major axis of the producing area, but the limits of production to the southwest, a prediction which was confirmed by two dry holes drilled outside the halo after this survey was of record and had been displayed. Note also how the subsurface trace of a fault, established by the drill, coincides with the long narrow Ethane anomaly inside the halo.

The survey above required 109 samples distributed over 4000 acres, at a contract price of less than $1,500.00. Such an investment is not unreasonable for information of this nature which is so intimately related to the limits of production.

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Progress and Trends in Geochemical Methods of Prospecting

By

J. BRIAN EBY

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

THE exploration for oil and gas by the use of geochemical methods has attracted attention because of the widespread development during the last twelve months. This is the first exploration process designed primarily to find the oil or gas in place. The other and better recognized geophysical methods have served the purpose of determining structure but gave no information concerning the presence or absence of oil or gas.

It is the purpose of this article to discuss briefly the present status of geochemical exploratory methods. There has always been considerable mystery attached to geochemical methods such as usually surrounds every new geophysical process. Mystery is usually caused by lack of direct information. To correct this situation insofar as possible concerning geochemical methods a series of photographs[1] is here presented illustrating many of the steps in conducting a geochemical investigation.

[1]Courtesy Subterrex, Houston, Texas.

Fig. 1. Collecting samples of surface soil for making analysis to determine soil wax content

The first step in a soil analysis survey, after the ground location of the sample has been determined, is the collecting of the two specimens, a shallow specimen from the surface for wax determination and a deeper specimen, from a depth of approximately 8 ft., for the determination of ethane gas. A typical truck, trailer, and crew on "location" is shown in Fig. 2. The actual process of collecting a shallow samples is shown in Fig. 1, and the collecting and bottling of a deep sample is shown in Fig. 3.

Upon arrival in the laboratory, the shallow and deep specimens are grouped to be examined respectively for wax or ethane. As indicated in Figs. 4 and 5, the samples for wax determination are carefully weighed and dried for the determination of moisture content. Apparatus for the extraction of soil wax from the topsoil samples is shown in Fig. 6.

The elaborate equipment necessary for the extraction of hydrocarbons from sub-soil samples is indicated in Fig. 7. The separation of ethane and propane requires huge quantities of nitrogen. It is interesting to point out that the soil-gas analyst has become one of the largest users of liquid nitrogen in the state of Texas. The last step in the analysis of soil samples for ethane gas is the reading of the Macleod gauge for volume of carbon dioxide resulting from the combustion of the ethane found in the soil.

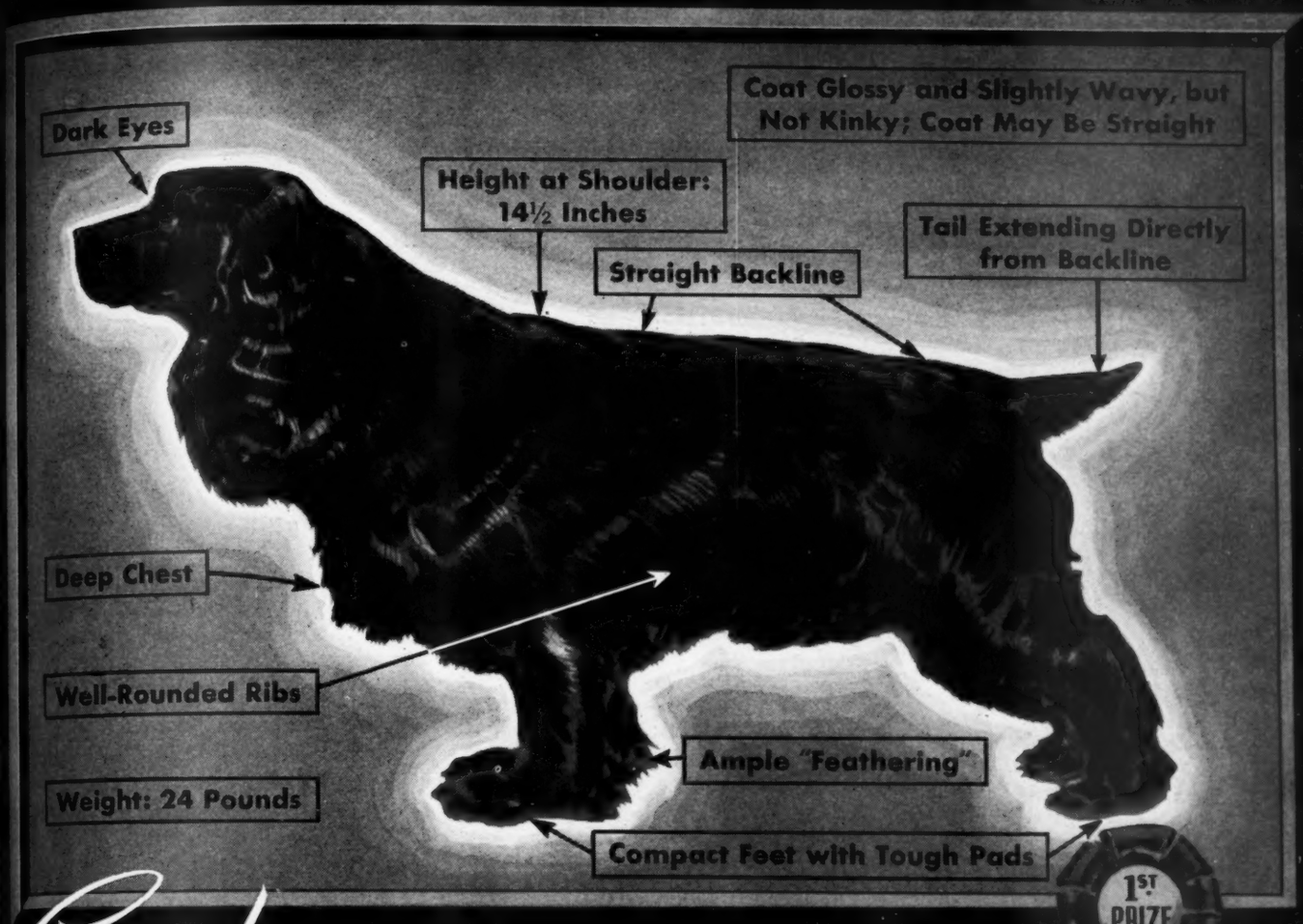
Upon completion of the analyses, the data concerning both wax and ethane content are placed on maps on which the respective collection stations are indicated. An example of such a map is that of the West Saxet field[2], northern Nueces County, Texas, as indicated by Figs. 8 and 9, which show wax content and ethane content, respectively.

West Saxet field was discovered in January, 1938, by a well producing from the Frio sand below 5600 ft. The soil analysis survey indicated by Figs. 8 and 9 was made during the month of March, 1938, when only four wells had been completed in the newly-opened field. In comparing the results

J. BRIAN EBY

is well equipped by his education and experience to write authoritatively on the subject of geophysics as applied to petroleum prospecting —He was graduated from Johns Hopkins University in 1918 with the degree of A.B., and in 1922 received a degree of Ph.D. in geology from the same institution—From 1919 to 1925 he was geologist with the United States Geological Survey, being stationed variously at Washington, D. C., in the Appalachian and in the Rocky Mountain states—He was in charge of the Geophysical Department of the Gulf Coast Division of the Shell Petroleum Corporation from 1925 to 1931, and since has been an independent geologist, making his headquarters at Houston, Texas.

[2]Maps, Figs. 8 and 9, presented by permission of Guy Warren, vice-president, Renwar Oil Company, Dallas, Texas.



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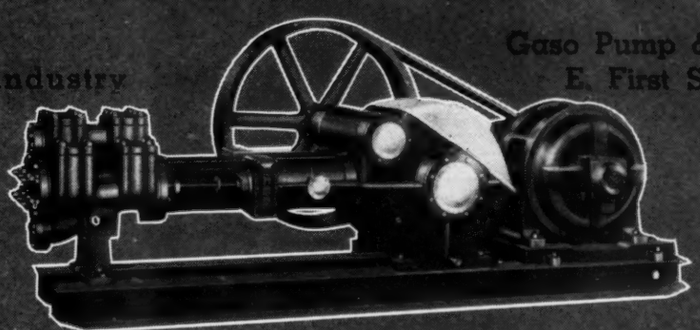

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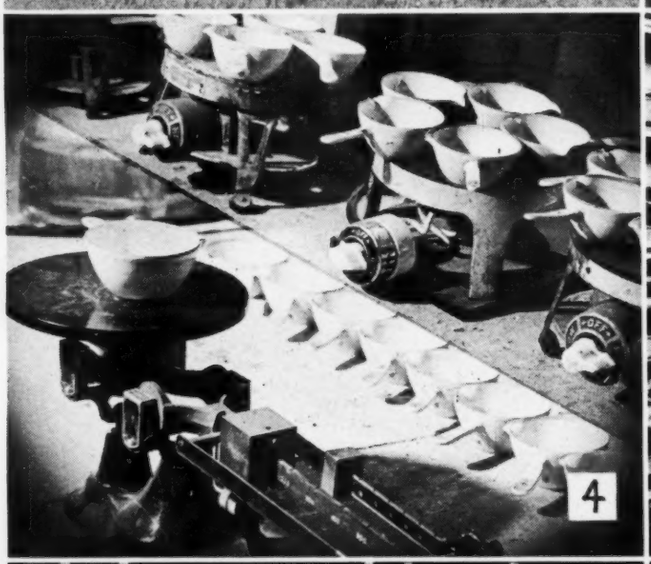

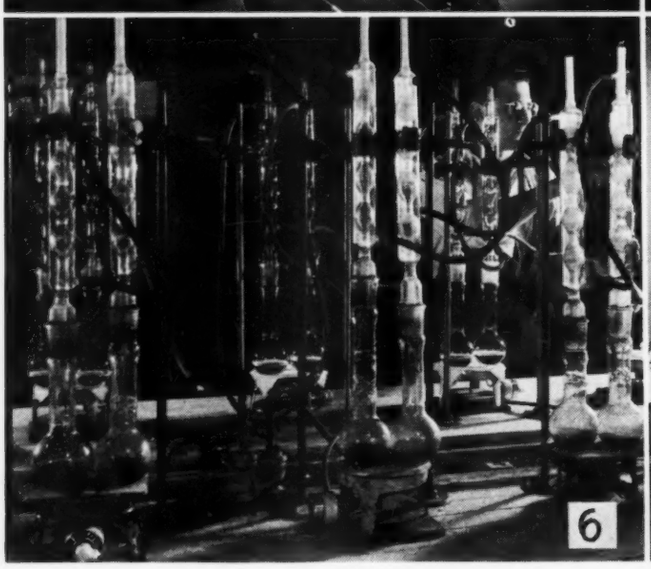

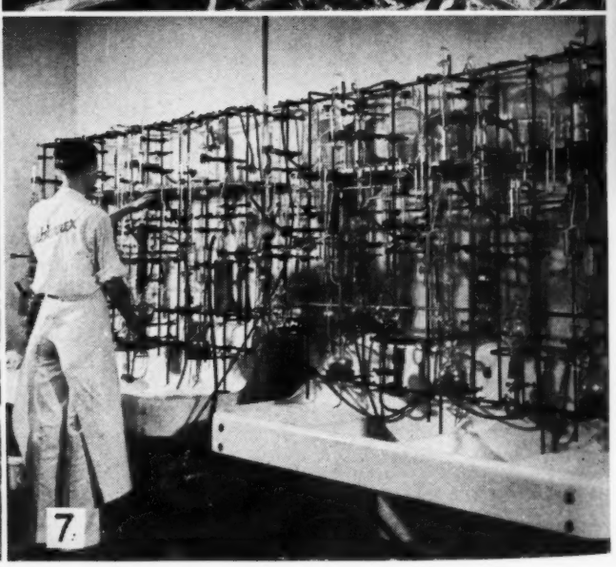

Fig. 2. Crew in field preparing to take shallow samples of soil for wax-content test
Fig. 3. Collecting samples of soil from 8-ft. depth and bottling in air-tight containers preparatory to testing for ethane content
Fig. 4. Sub-soil samples are accurately weighed and dried for determination of moisture content
Fig. 5. Soil samples drying prior to laboratory treatment
Fig. 6. Apparatus for the extraction of soil wax from the top soil samples
Fig. 7. A part of the elaborate equipment necessary for the extraction of hydrocarbons from sub-soil samples

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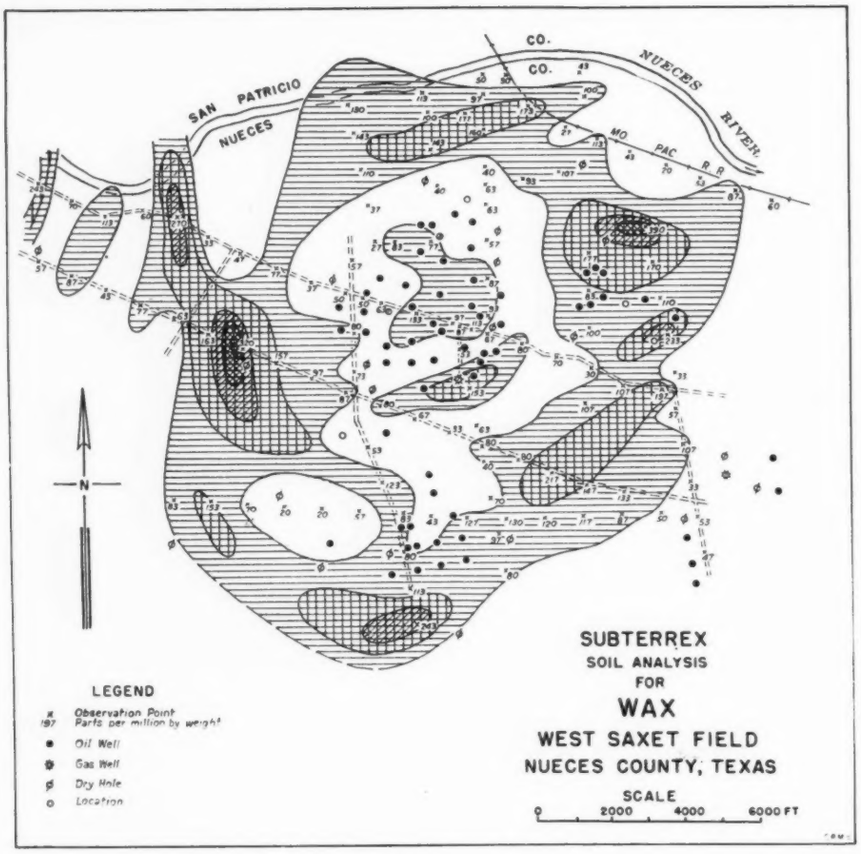

Fig. 8

of the wax and ethane surveys it was found that the two pictures did not coincide, suggesting the possibility of commercial accumulation in addition to that already discovered. The final data showed that the soil-wax halo lay outside of the ethane halo, indicating leakage from two oil horizons of different areal extent. This conclusion was confirmed by the later discovery of oil in a zone at 3800 ft., above the previously discovered deeper-seated Frio sand but not coincident with it in areal distribution.

Soil surveys are now being conducted in many parts of the United States. Satisfactory analyses have been made from samples collected in California, West Texas, the Mid-Continent, Southwest Texas, and the Gulf Coastal sections of Texas and Louisiana. At least one crew is operating in Venezuela at the present time. For several years geochemical petroleum exploration has been conducted in the Russian oil-bearing provinces.

Among oil operators and geologists generally, the analysis of soil for significant oil or gas constituents or residues is recognized as having excellent possibilities of becoming a successful and recognized method of exploration.[3] It is impossible, however, to state at this stage of development just what the future holds for it. The geochemists on their part are pushing the development of their exploratory program with tremendous energy and they are receiving the backing of many of the larger oil operators. The events of the coming year should tell much concerning the ultimate success of the method.

[3]Within the last year Geophysical Service, Incorporated, Dallas, Texas, has undertaken soil surveys, specializing in the determination of occurrence of liquid hydrocarbons and mineralization significant to oil and gas accumulations. This concern has recently issued a booklet by Dr. Eugene McDermott entitled "Soil Surveys" discussing briefly the method of collecting and examining soil samples for these constituents. Included are plats of liquid hydrocarbons and mineralization on maps of the LaRosa field, Refugio County, Texas; the Riverside area, Nueces County, Texas; the Atlanta area, Columbia County Arkansas, and the Ohio-Coles area, Kern County, California. Several laboratory photographs are likewise included.

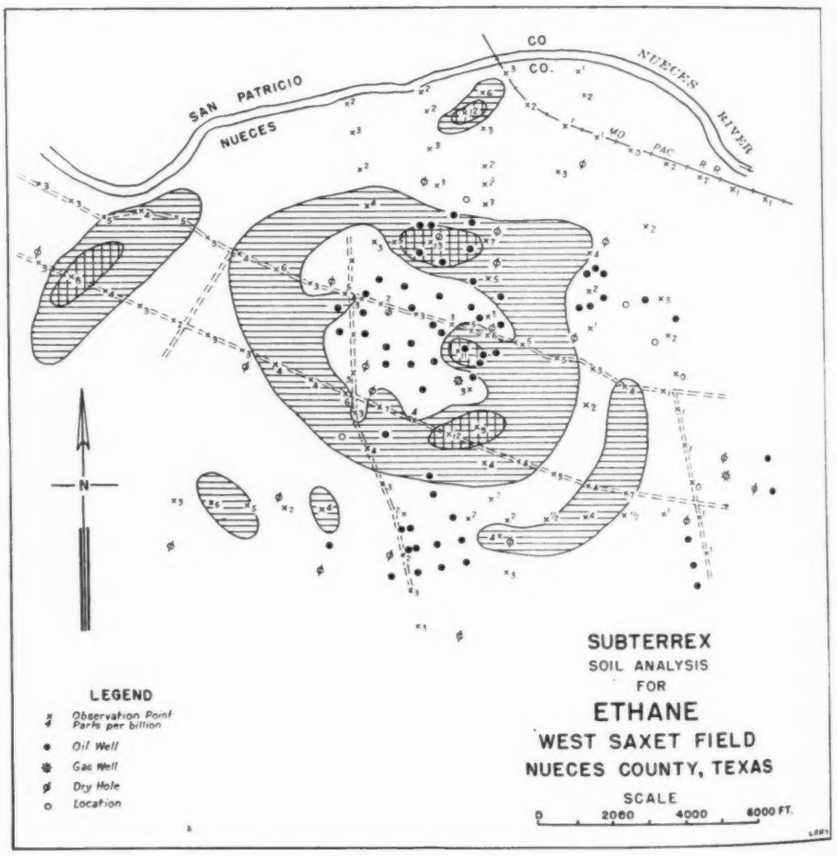

Fig. 9

Advancements in the Use of the Gravimeter in Oil Exploration

By

L. M. and F. W. MOTT-SMITH

Mott-Smith Corporation, Houston, Texas

THE use of gravity surveys in the search for geologic structures favorable to the accumulation of petroleum has been recognized as an important and valuable exploration method for many years. Up to a few years ago, such gravity surveys were obtained almost exclusively by means of the torsion balance, which was for a considerable period the only type of instrument capable of sufficient accuracy. The need, however, was felt for a more rapid and direct method of measurement than that afforded by the torison balance. To fill this need much effort was devoted by several organizations toward the development of direct-reading gravity measuring devices, which have been named gravitymeters or gravimeters. These instruments have during the past few years been rapidly gaining in popularity and indeed have rendered the torsion balance practically obsolete for the majority of exploration programs. Among the instruments in general use may be mentioned those developed by the Humble and Gulf oil companies, by Brown, by Romberg and Lacoste, and by Mott-Smith in this country; by Thyssen, and by the Askania Corporation in Germany. The first gravimeter was placed in regular service in this country early in 1931 but it was not until 1935 that the value of the use of this instrument became recognized. By June 1, 1939, there were approximately 60 gravimeter crews operating in the United States and a number in many other parts of the world.

In order to be of value for oil exploration, instruments used for this purpose must be capable of measuring about one ten-millionth of the total acceleration of gravity. To accomplish this, considerable instrumental refinement is necessary, and a large measure of the success of gravimeter surveying must be credited to the development of suitable apparatus.

The gravimeter consists essentially of a mass supported by an elastic member, and a means of measuring variations in position of the mass caused by variations of the gravitational attraction on the mass. Numerous difficulties are involved in the use of a mass suspended by a spring for making accurate measurements of the variations of gravity. First, there is the problem of devising a sufficiently sensitive means for measuring the displacement of the mass. For example, suppose that a mass is suspended by a helical spring, which is extended a distance of six inches at one locality. If the device is moved to a place where the acceleration of gravity differs from the initial by one part in ten million the extension of the spring will change by six ten-millionths of an inch. This displacement is much too small to measure by ordinary methods. Several methods have been proposed and put into successful practice for overcoming this difficulty. The most satisfactory of these involves the use of a more complicated spring system which behaves like a simple spring having a very large extension, so that the displacement is increased to about one hundred times that of the longest practicable simple spring. The combination of such a system with measuring microscopes of high magnification or refined optical levers has solved satisfactorily the problem of obtaining sufficient reading accuracy.

Two further major difficulties were until very recently the chief obstacles in the development of a satisfactory gravimeter. One of these is change in extension of the elastic system caused by change of temperature. This is because of two effects, ordinary thermal expansion and change in the elastic properties of the spring material as the temperature changes. That such variation of length must be either taken into account with great accuracy or, preferably, eliminated almost entirely can be appreciated if it is recalled that a steel spring increases in length by about two parts in ten thousand per deg. cent. rise in temperature. Thus, changes of length due to atmospheric

L. M. MOTT-SMITH

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Fig. 1. Gravimeter observations being taken in a jungle location in Colombia, South America

temperature variations are very large in comparison to those caused by the small gravity variations it is desired to measure. This difficulty has been overcome by three principal methods, used at present in the more successful instruments either in combination of all three or some of the possible combinations of two. These are: (1) compensation of the temperature effects by means of opposing differential expansion; (2) use of new spring materials having reduced temperature coefficients, and (3) use of thermostats to maintain approximately constant temperature. Of any single method, the latter, maintaining the instrument at constant temperature with sufficient accuracy is undoubtedly the most effective, because compensation to the required accuracy is next to impossible over the great range of atmospheric temperatures likely to be encountered in field work, and because there is no known spring material whose temperature coefficient is low enough to permit accuracy over this wide range. In the instrument developed by Mott-Smith, the method selected involved developing a thermostatic system capable of maintaining a constant temperature within one-thousandth deg. cent. under field conditions.

Finally, the most troublesome difficulty to overcome is the imperfect elasticity, characteristic to some extent of all elastic materials when attempting to attain great accuracy. This imperfection appears in two distinct manners, termed creep and elastic after-effect. Creep is simply a gradual yielding of an elastic material under load. This effect, though usually negligible in ordinary engineering applications, may, in unseasoned common steel springs, be as great as an increase in length of twenty parts in ten million per hour. These springs are, therefore, unsatisfactory for a gravimeter. Elastic after-effect appears in the imperfect return of a spring to *almost* its original length immediately after a displacement, followed by a gradual return to its original position, the rate of which depends on the amount of displacement and the length of time the spring has remained displaced. This behavior, if present to an appreciable extent, impairs the accuracy, inasmuch as it is impossible to allow for it with sufficient certainty. Modern gravimeters probably all make use of special elastic material, or specially treated material, for the purpose of making these effects as small as possible. The exact nature of the materials and also their treatment are carefully-guarded trade secrets and are largely responsible for the success of present-day instruments.

Besides these main problems there are numerous secondary ones, among which an important one is that of calibration. A gravimeter must be calibrated so that the change in the acceleration of gravity can be determined from the measured displacement of the mass. This may be done by several methods in the laboratory, but it is desirable to provide a means by which calibration can be carried out in the field because changes in sensitivity may occur during a relatively short time. For instance, when dealing with a delicately balanced elastic system, small changes in the geometry of the system, caused either by relative motion of supports, or by readjustment to compensate for creep or large changes of gravity, may cause slight changes in calibration. One of the best methods of calibration involves the addition of a small mass to the main mass and a reading of the resulting displacement. In one type of gravimeter the mass is subjected to a small calibrating force by electrostatic attraction. It is also possible to calibrate an instrument by making observations at different heights above the earth's surface in a building, or by observations at stations whose gravity difference has previously been measured with pendulum or torsion balance.

(Continued on Page 89)

Fig. 2. A gravimeter set-up on a cypress stump in a Louisiana marsh

Fig. 3. Gravimeter being transported by hand through a Louisiana swamp

(Continued from Page 86)

A satisfactory instrument must not suffer a permanent displacement of the mass or change in calibration from jars or vibration such as would be encountered in transporting or setting up the instrument.

The damping of the elastic system hould be nearly the value that makes it aperiodic. Otherwise a disturbance such as might be caused by a passing automobile would set the system into oscillations that would persist for such an extended period that observation would be impossible if disturbances were frequent. Normal vibration of the ground should not cause appreciable unrest of the elastic system.

The gravimeter is usually transported in a light truck. In order to make an observation, the instrument must rest firmly on the ground. For this purpose it may be removed from the truck and deposited on the ground, but a better method used by several organizations is to support the gravimeter inside the truck on a tripod arrangement that can be lowered to the ground through holes in the floor. Fig. 10 shows the instrument on such a tripod ready for observing. This method is advantageous in that the gravimeter is continuously shielded from the elements so that operations may be carried on in inclement weather.

To make a survey with the gravimeter, the first task is to lay out a set of station locations in the area to be explored. This is done by a surveying party, marking station sites by flags and stakes, placed along roads or trails wherever possible. The area is checkerboarded with stations as uniformly as possible. For most reconnaissance work one station per square mile is sufficient. In some areas when more detail is needed as many as ten stations to the square mile may be established, though this number is rarely needed except when making a detailed survey of a definite gravity anomaly or in regions where very abrupt changes of gravity occur. It is also the duty of the surveyors to obtain the elevations of all the stations relative to that of the main base and to record them on a map. This work proceeds with the actual gravity survey, keeping sufficiently ahead so that the instrument party is not delayed by having to scout roads and mark the stations.

The instrument party begins its work by setting-up the gravimeter at the main base. The instrument is first adjusted so as to bring the indicator to a convenient point on the scale. A scale reading is then taken, followed after a short interval by a second observation, to guard against mistakes and to increase the accuracy. This procedure is then repeated at several successive stations. After five to ten stations have been occupied the meter is brought back to the main base for a check observation. Usually the next step is to make a subsidiary base station out of one of the new stations just taken. The station selected is situated conveniently for further expansion of the survey and is established by taking a second observation there. Thus, a base is simply a field station whose gravity value relative to another has been made more certain by being occupied twice. The survey then proceeds in the same manner from the subsidiary base as initially from the main base, check readings being taken at this base instead of the original one. In this way the area is gradually covered with a series of bases and ordinary stations. The reason for proceeding in this manner is to avoid long trips back to the main base for check readings.

While the work in the field is in progress a computer at the field office assembles the results and constructs the gravity map. The process of computation is as follows: The instrument-

Fig. 4. Gravimeter being transported by a railway tram car in a Louisiana swamp on rails laid for logging purposes

Fig. 5. Preparing for a difficult gravimeter set-up on a steep river bank, Colombia, South America

scale readings are first converted into milligals by using a calibration curve. The next step is to plot a so-called drift curve by plotting the value of gravity against the time at which the reading was taken. Fig. 11 shows a drift curve representing the work of an average day. Plotted as ordinates are gravity readings in milligals, as abscissas the times at which the readings were taken. Inspection of such a plot gives considerable information on the work of that day. It also serves as a partial check on whether the instrument is operating properly and is used to compute the difference in the values of the acceleration of gravity between the several stations.

On the day represented by Fig. 11 the operator first occupied base 4 and made an observation. He then occupied stations 16 to 22, inclusive, and returned to the initial base for a check reading. If the instrument were perfect, he would have obtained exactly the same reading. Actually, due to slight instrumental inaccuracy, a reading was obtained about 0.05 milligal less than before. The instrument was then returned to station number 22, thus obtaining a second observation at this station and establishing it as a new base. Four new stations were then observed and a check reading at the new base taken. Station 26 was then established as a base and finally seven new stations were observed, with two check readings at base 26. It will be noted on this particular day the instrument was set up 25 times, 18 new stations were determined, and two new bases established.

The difference in the acceleration of gravity between the various bases and stations is next taken from the drift curve. Small discrepancies between the first and second observation at a base are allowed for by drawing a straight line through the points as shown. This procedure involves the assumption that the instrument drifted at a constant rate between observations. If this drift were appreciably erratic, considerable error would be made, but experience has shown that this method is sufficiently accurate for practical purposes. The gravity difference between each station and the base to which it is referred is assumed to be the number of milligals between the station point and a point on the drift line vertically above or below it.

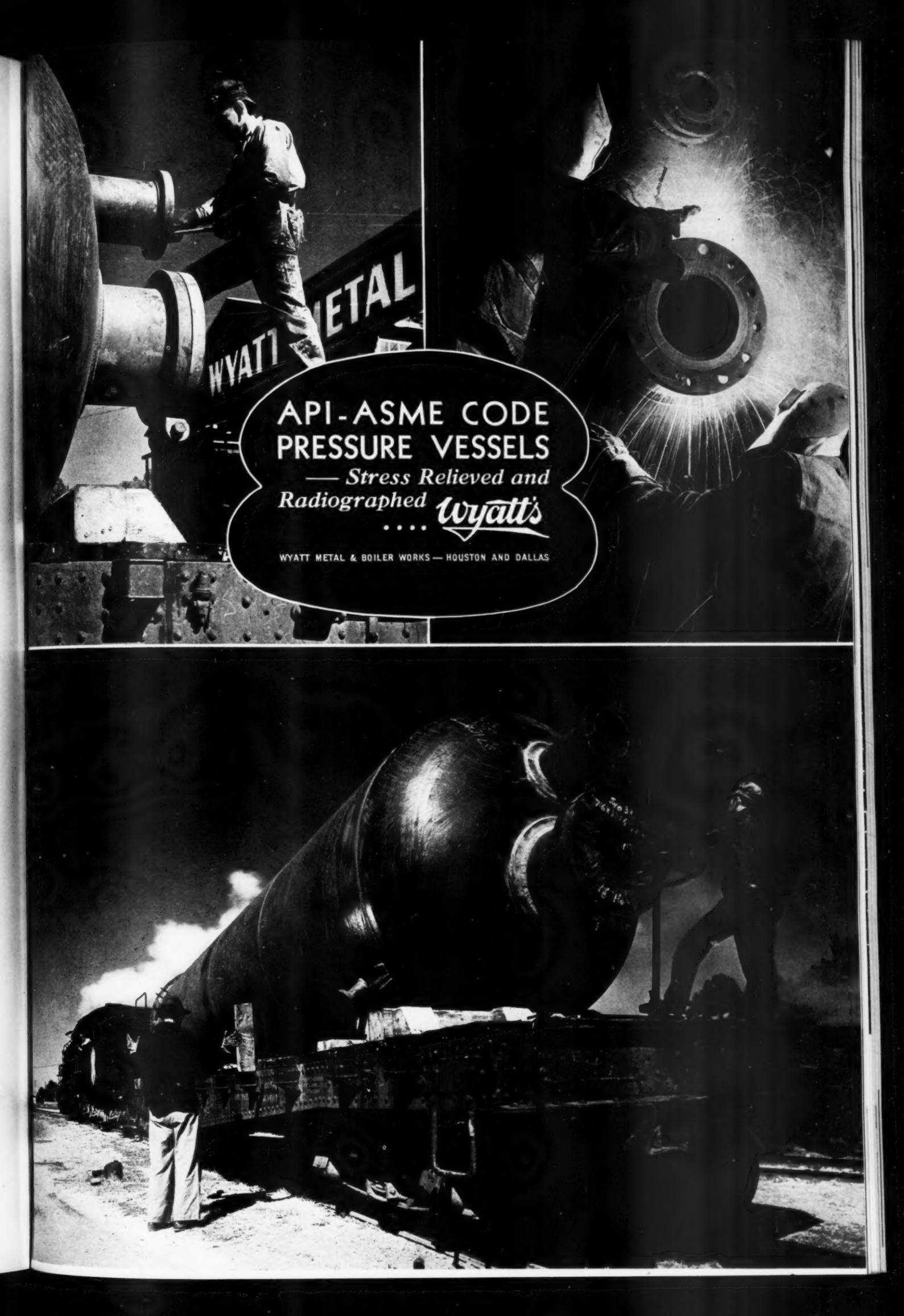
Knowing the difference in gravity between each station and one of the bases, and the differences between bases, the gravity difference between all stations and bases and the main base can at once be obtained by addition. At the outset the main base in each area is given an arbitrary value, preferably chosen great enough so that none of the station values are negative to avoid the inconvenience of carrying

Fig. 6. Moving gravimeter equipment through the jungles of Colombia, South America

negative numbers. In all gravimeter work the actual numerical value of the acceleration of gravity is not obtained, as the instrument is capable only of giving the difference in gravity between two stations. This, however, is not a disadvantage because in mapping a gravitational anomaly only the variations in gravity are required. If absolute gravity values are desired, the gravimeter survey must be connected with a pendulum gravity station.

Before plotting the observed gravity values on the map two corrections

Fig. 7. Transferring gravimeter equipment from truck to wagon in Gulf Coast, Louisiana, swamp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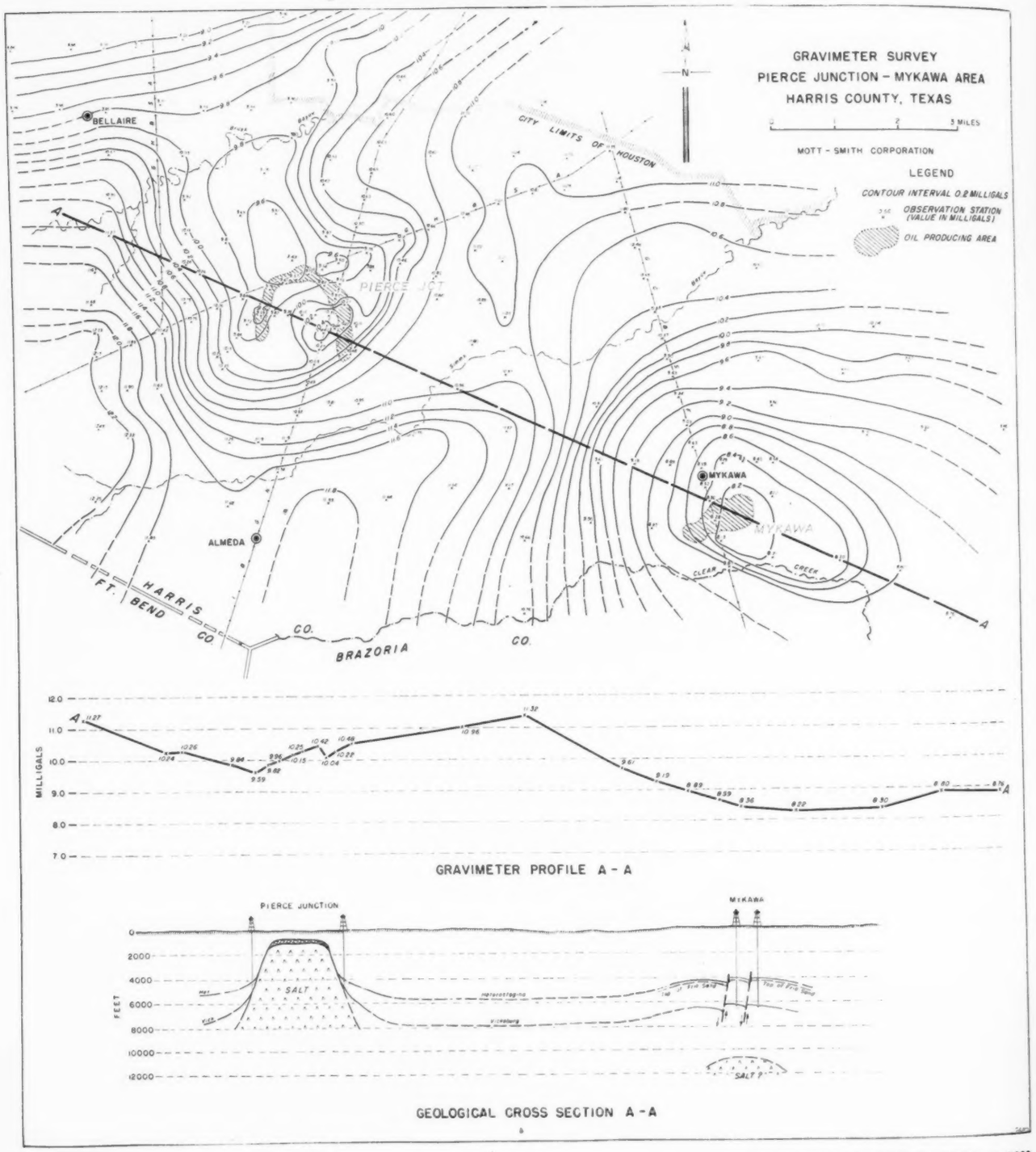
must be applied. These are termed the elevation and the latitude correction. The elevation correction takes into account changes in gravity caused by changes in elevation of the station. The acceleration of gravity decreases by between six- and eight-hundredths milligals per ft. of increase of elevation. Accordingly, except in an exceptionally level region, the observed gravity values will vary considerably from station to station simply because of changes of elevation. After correction, the gravity values are the same as if they had been observed on a perfectly flat land surface, and are then suitable for detecting slight variations due to buried structures.

The exact value of the elevation correction depends on the density of the underlying materials. The proper elevation correction to be used in any region may be calculated if a sufficiently good estimate can be made of the density of surface materials. It is also possible to determine the correction experimentally by obtaining gravity values at a series of closely spaced stations along a line chosen to include considerable changes of elevation. A value of the correction is chosen by trial and error that eliminates the effect of elevation difference in the corrected gravity values. Having established the proper constant, the observed gravity values are all corrected to the elevation of the main base by adding or subtracting the proper amount from each.

The latitude correction is introduced to eliminate from the final gravity

Fig. 8. Gravimeter survey in a proven oil area



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Calcasieu Bank No. 1	8,905
Thomas No. 1	9,552
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Donovan O'Connor No. 1 (still drilling)	8,159
Donovan O'Connor No. 2 (side-tracked hole)	2,283
	46,921 feet

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Fig. 9. Gravimeter work is being conducted in many parts of the world. This camel train is a gravimeter party preparing to take observations near El Arish, Egypt

map the change of gravity that normally occurs due to change of geographical latitude. This change is approximately an increase of one milligal per mi. of northerly displacement. To make the correction, curves are drawn from the standard Bowie formula giving the normal value of gravity as a function of the latitude. The latitude of the main base and that of each field station is obtained from the map. For each station the gravity difference caused by difference in latitude is read off the curve and subtracted from the observed gravity differences.

The results are now ready for mapping. The gravity value for each station is entered upon the map. A pictorial representation of the variations of gravity is obtained by drawing gravity contours, that is, lines of constant gravity. The contour interval generally used is one-half milligal. In areas surveyed in greater detail or in which gravity changes of considerable magnitude occur in a relatively short distance, contours may be placed at smaller intervals.

An example of a gravity survey is shown in Fig. 8*. It is a survey of an area in the vicinity of Houston, Texas. This survey, made in nine working days, includes 169 stations, and covers an area of approximately 100 square miles. The map has been contoured at 0.2-milligal intervals. The stations were generally placed one-half to one mile apart, though in one portion a separation of one-quarter mile was used to obtain greater detail.

There are two producing oil fields in this area, Pierce Junction and Mykawa. The Pierce Junction field is around a piercement type of salt dome. The structure consists of a substantially vertical salt plug of nearly circular horizontal section and approximately one mile in diameter. The salt is surmounted by a cap rock about 250 ft. thick. The top of the salt is at a depth of approximately 950 ft. This structure results in a rather complicated gravity picture, but one which is characteristic of this type of dome. The picture is complicated by the presence of a regional change of gravity, values increasing toward the south, and also by the neighboring gravity minimum caused by Mykawa toward the southeast. The main gravity feature is a large so-called minimum nose, clearly indicated by several contours. This type of feature occurs when a gravity minimum is superposed upon a regional or large-scale change of gravity. The gravity minimum is caused by the salt mass, which has a lower average specific gravity than the surrounding beds. The actual decrease attributed to the dome is in this case about two milligals and the effect of the dorne is noticeable over an area bounded by a distance of about three miles from the center. There is also a small positive gravity effect superposed upon the large minimum, appearing as a maximum of 0.4 milligal near the center of the dome. This feature is caused by the relatively dense cap rock. The maximum is somewhat displaced from the actual position of the cap rock as outlined by the oil-producing area at the periphery of the dome. The displacement is principally caused by the regional gravity change and can be corrected by applying corrections for regional change. In using gravity work for detailing such structures, corrections for regional change are made whenever it is large enough to be important. Even without correction, however, such a gravity picture can often locate the structure accurately enough for reconnaissance purposes.

The Mykawa field, shown in the lower right-hand corner of the map, is on an uplift presumedly produced by a deeply buried salt mass. The salt mass must lie at a depth of more than 7350 ft., the depth of the deepest well,

*The authors are indebted to Dr. J. Brian Eby for supplying the geological data presented in this figure.

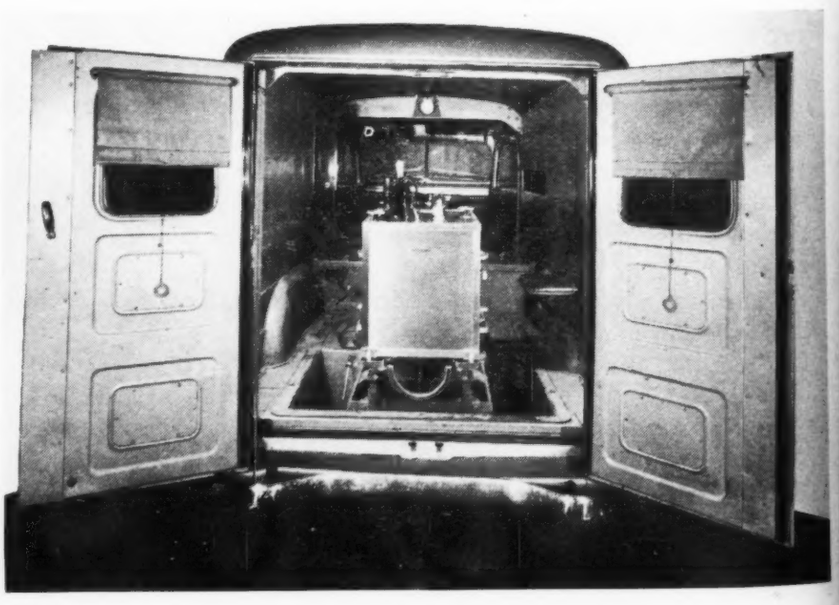
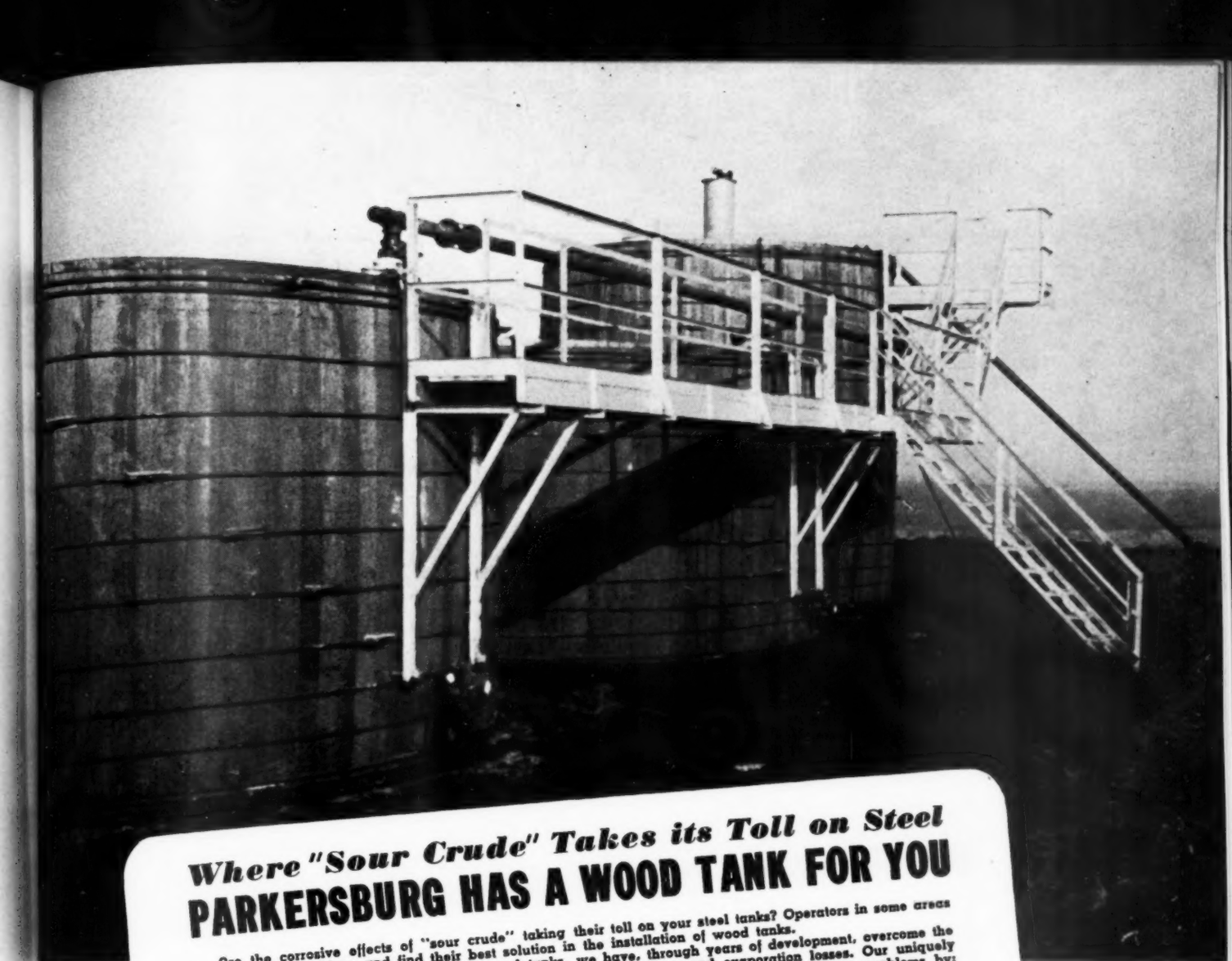


Fig. 10. Detail view of gravimeter mounted in panel truck adapted for setting-up directly through the floor of the truck on any location to which the truck is accessible



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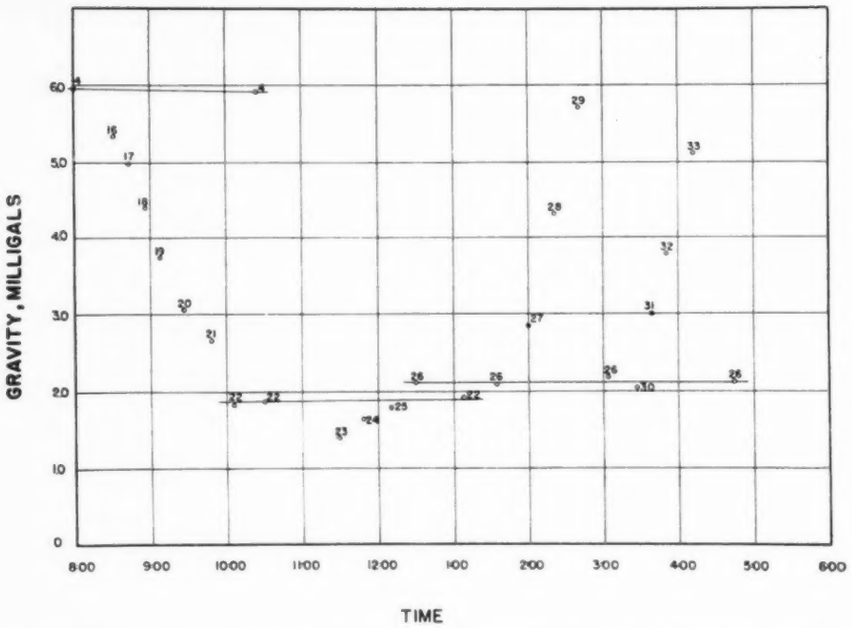


Fig. 11. Drift curve

as the salt was not found in any of the wells. Production comes from sands at depths of 4100 to 4900 ft. The structure appears as a pronounced gravity minimum extending over considerable area. In fact, it extends considerably beyond the limits of this survey in a southeasterly direction. The field is somewhat displaced from the center of the minimum, but such displacement could have been predicted by noting that the value of gravity drops toward the minimum much more rapidly on the northwest than on the southeast. This condition is produced by a salt mass in which the center of gravity of the salt body is not directly below its apex. The center of the minimum is of course very nearly above the center of gravity, and the top of the uplifted layers of the sedimentary rocks is above the apex of the salt mass. From study of the exact shape of such a minimum it is possible to make a good estimate of the location most favorable for finding production.

The value of a gravity map depends largely upon its accuracy. Various types of tests have been made to determine this accuracy. Aside from mistakes such as errors in reading the scale or in computation, the error arises from three principal causes. The first is erratic fluctuations in the instrument-reading from such causes as temperature fluctuation, elastic after-effect, effect of jars, etc. The second is inaccuracy of the calibration curve, and the third is error in making the latitude or elevation corrections caused either by inaccuracy of surveying or by use of an incorrect elevation correction constant.

The magnitude of the first type of error may be determined readily by noting the deviations of a succession of observations at the same station. In making such a test it is evident that actual field conditions should be duplicated closely. The procedure, accordingly, is to occupy a station and make an observation in the manner customarily employed in normal field work. The instrument is then transported in its truck a distance of one mile and returned to the same station. Here a second standard observation is made. This process is repeated until ten or more observations have been taken. A series of 11 such observations plotted as a drift curve are shown in Fig. 12. These data were treated as follows for the computation of the probable error of a single occupation of a station. The best straight line is first passed through the observed values. This may be done readily by a trial and error method or by the usual least-squares procedure. The deviations of the observed values from the drift line are then computed, and finally the probable error is obtained by the standard procedure of multiplying the square root of the average square deviation by the factor 0.67. In this test the mean deviation is found to be 0.06 milligal and the probable error of a single observation 0.04 milligal. The largest deviation from the drift line occurred at the second trial and is 0.10 milligal. This accuracy is within the limits necessary to obtain useful gravity maps.

The error caused by inaccuracy of calibration can partly be tested by determining the error of closure of closed loops of gravity differences. If the scale readings are converted into gravity values by means of an incorrect calibration curve, which might be the case if the sensitivity of the instrument changed during the course of a survey, errors of closure will appear. There is, however, also the possibility that an initially incorrect calibration might give proper closure, and yet all the measurements might be too large or too small by a constant percentage.

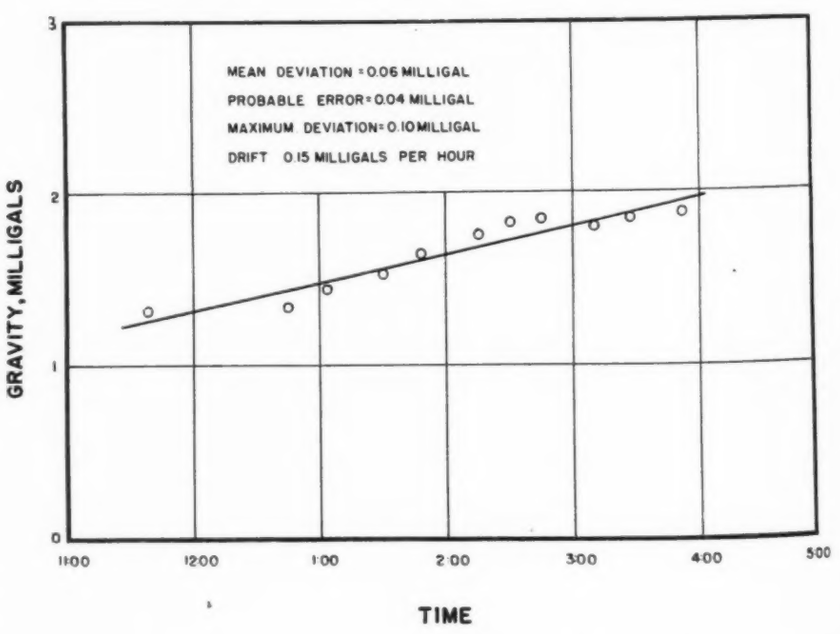
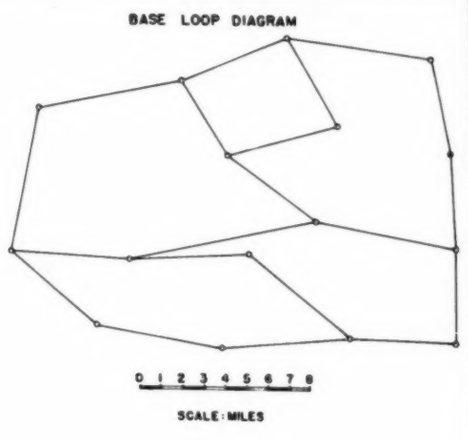


Fig. 12. Plot of repeated observation at the same station to determine effect of transportation, etc., on instrument accuracy

LOOP NO.	GRAVITY DIFF. MILLIGALS	NO. OF BASES	ERROR OF CLOSURE MILLIGALS
1	24.26	7	.01
2	8.44	6	.24
3	32.05	9	.25
4	24.36	7	.11
5	12.59	6	.32
6	9.13	4	.20
7	14.60	6	.34
8	38.47	4	.35



AVERAGE GRAVITY CHANGE AROUND LOOPS = 25.12 MILLIGALS

AVERAGE ERROR OF CLOSURE = 0.23 MILLIGALS

EACH BASE OCCUPIED TWO TIMES

Fig. 13. Base loop closure data

This possibility may be detected in several ways. One method is to make observations at different known elevations in a building. Another is to check the gravimeter against gravity differences known from pendulum observations. Gravimeters are considered satisfactory if such tests indicate calibration errors of less than one percent.

Fig. 13 shows a table giving the essential data for a number of closure tests. These were chosen so as to represent average results. It will be noted that the error of closure averages 0.23 milligal.

Errors caused by inaccurate latitude and elevation corrections can be reduced to virtually negligible proportions by sufficiently accurate surveying and by taking care to use the proper elevation correction constant. It is practicable to establish the latitude of each station to within about one-twentieth of a mile. Thus the error in the latitude correction is about five hundredths of a milligal. It is also perfectly feasible to require closure of level-line loops to within one foot, so that error from incorrect elevation is not greater than about seven hundredths of a milligal.

In conclusion it may be of interest to compare the gravimeter method of exploration with the older torsion-balance method as regards the value of the information obtained, the time required, and the cost, to show the progress that has been made in gravitational surveying. The accuracy of gravity-maps obtained with a torsion-balance depends more on the character of the terrain than of those obtained with gravimeters. In regions in which there is considerable relief or irregular surface materials the gravimeter is distinctly superior. The reason for this is that the torsion-balance is much more strongly affected by nearby terrain irregularities. Two examples of the effect of local disturbances on the two instruments are shown in Fig. 14. It will be noted that a relatively small local disturbance such as might be produced by a change in surface density or a buried boulder has a very marked effect on the reading of the balance, whereas the effect on the gravimeter is negligible. If terrain effects are small, the accuracy of the two instruments is comparable over areas of a few square miles. For outlining gravity anomalies, however, covering areas of the order of fifty to several hundred square miles, as is sometimes desirable in following certain geologic trends, the accuracy of the gravimeter is considerably greater. On the other hand the torsion-balance is probably more suitable for detecting small-scale shallow structures, as for example a fault of small displacement extending nearly to the surface. Comparison of the speed of the two methods is best made by comparing two parties of the same size and cost. For the gravimeter a typical party would consist of a party chief, and two men, plus two surveying parties of two men each, or a total of seven men. One gravimeter would be used. A comparable torsion-balance party would also have about seven men, and use two torsion-balances. The rate of covering area by the gravimeter of course depends on the spacing of the stations and on road conditions. It is customary to take for an average reconnaissance survey a spacing of about one station per square mile. Under average road conditions, it is possible to average at least 20 new stations per day. Thus, about 20 square miles per day can be covered, or about 500 square miles per month. The comparable torsion-balance crew obtains 8 stations per day. To obtain satisfactory accuracy for reconnaissance work the stations must be placed about one-quarter of a mile apart. Lines of stations are usually run in such a manner that there are about four stations per square mile. Thus an area of two square miles per day is surveyed, or about 50 square miles per month. The gravimeter is therefore ten times as rapid as the torsion-balance. Its greater speed makes its cost per square mile of survey considerably less.

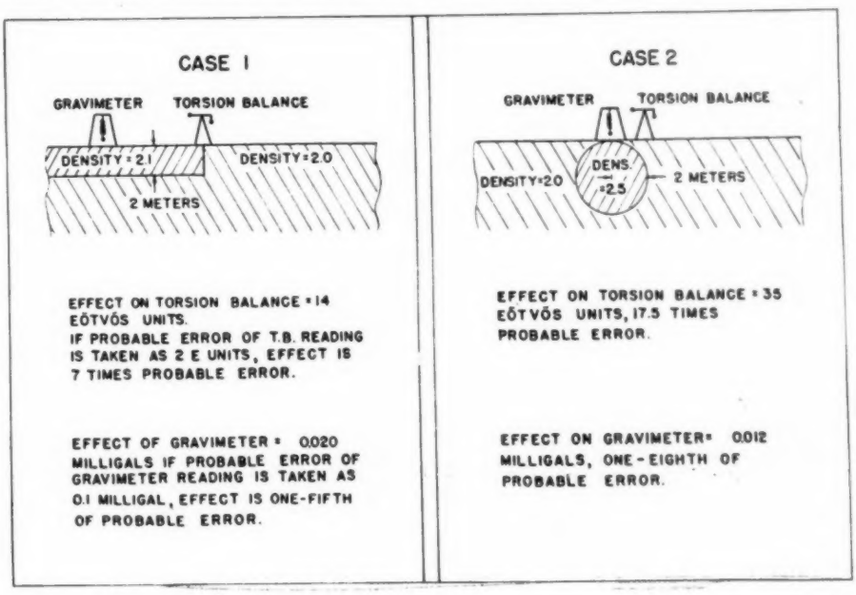

CASE 1
GRAVIMETER
TORSION BALANCE
DENSITY = 2.1
DENSITY = 2.0
2 METERS
EFFECT ON TORSION BALANCE = 14 EÖTVÖS UNITS.
IF PROBABLE ERROR OF T.B. READING IS TAKEN AS 2 E UNITS, EFFECT IS 7 TIMES PROBABLE ERROR.
EFFECT OF GRAVIMETER = 0.020 MILLIGALS IF PROBABLE ERROR OF GRAVIMETER READING IS TAKEN AS 0.1 MILLIGAL, EFFECT IS ONE-FIFTH OF PROBABLE ERROR.
CASE 2
GRAVIMETER
TORSION BALANCE
DENSITY = 2.0
DENS. = 2.5
2 METERS
EFFECT ON TORSION BALANCE = 35 EÖTVÖS UNITS, 17.5 TIMES PROBABLE ERROR.
EFFECT ON GRAVIMETER = 0.012 MILLIGALS, ONE-EIGHTH OF PROBABLE ERROR.

Fig. 14. Comparison of the effect of disturbing masses on the gravimeter and on the torsion balance

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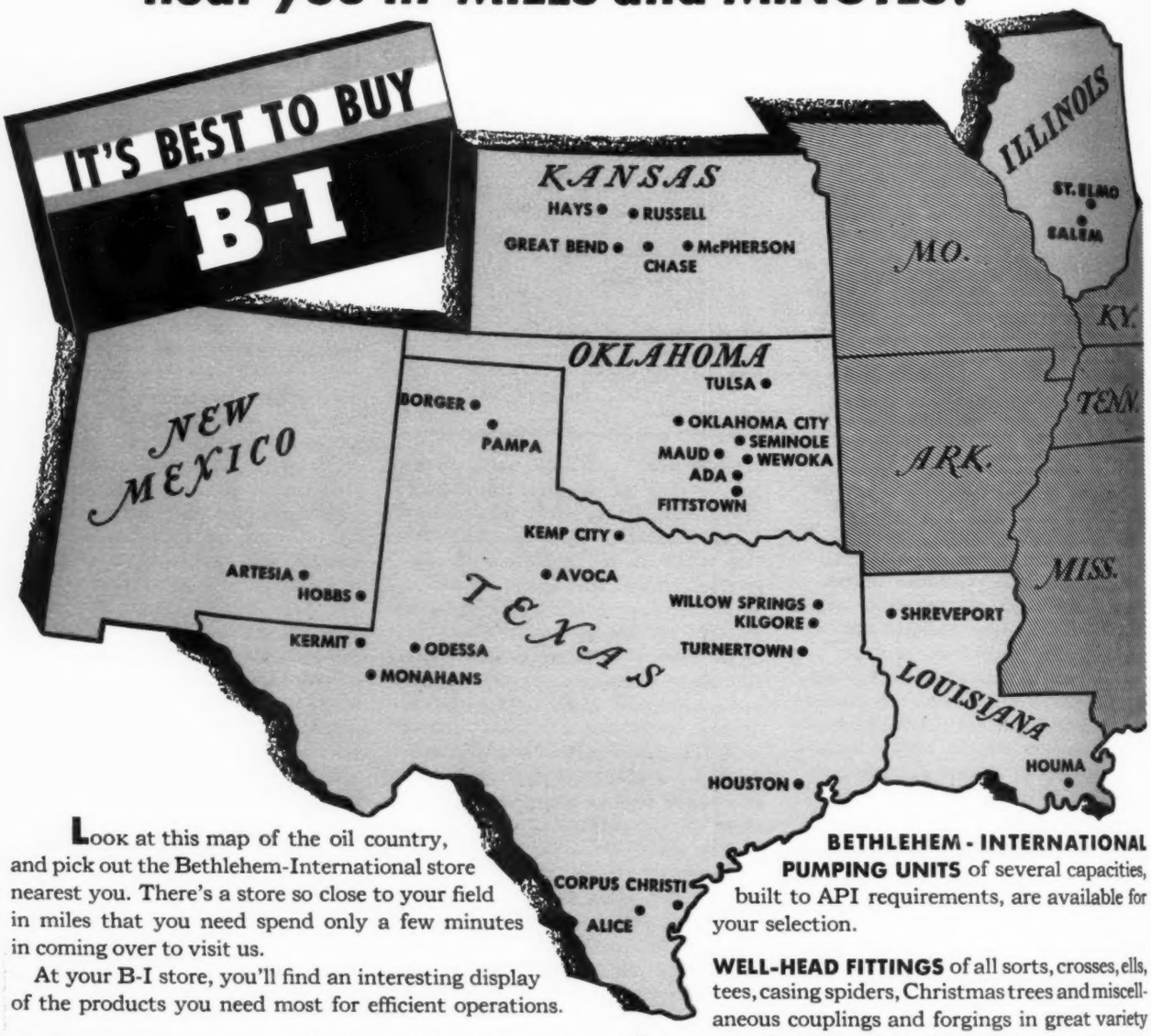

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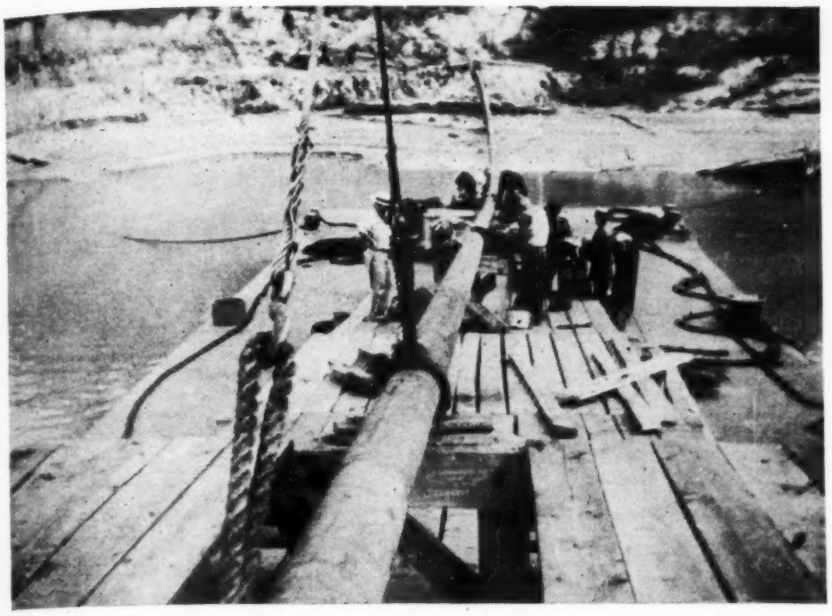

Laying five lines of 10-in. pipe by the "stove-pipe" method, arc-welded, across the Mississippi River

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

Welded Pipe-Line Construction Features Greater Use of "Stove-Pipe" Method

By A. F. DAVIS

Vice-President, The Lincoln Electric Company, Cleveland, Ohio

IN 1938, one-third of the total miles of electric-welded pipe line constructed by one of the country's leading pipe line welding contractors, was welded by the "stove-pipe" method. Of the total of 466 miles of pipe that this company laid, five lines having a combined length of 159 miles were "stove-piped." These included an 18-mile, 8-in. oil line for the Pure Oil Company; a 24-mile, 8-in. oil line for the Illinois Pipe Line Company; an 11-mile, combination 2-, 3-, 4-, 6-, 8-, and 12-in. oil line for the Carter Oil Company; a 98-mile, combination 6-, 8-, and 10-in. oil line for the Central States Pipe Line Company, and an 8-mile, 6-in. oil line for the Magnolia Pipe Line Company.

Data on the pipe lines on which the stove-pipe method of construction was used are shown in Table 1.

Use of "Stove-Pipe" Method

In the stove-pipe method of constructing pipe lines, each joint is laid and welded individually. All the welds are bell-hole, or positioned, welds. The method was originated for construction of lines through rough or muddy terrain where it is difficult to complete more than one mile of line per day using the conventional "firing-line" method. Under such adverse working conditions, the stove-pipe method has proved less expensive. The economy results principally from the elimination of the line-up crew, the function of which in firing-line welding is to line-up the pipe preparatory to welding. A line-up crew cannot work advantageously through mud, swamps, rock, and rough country.

The use of the stove-pipe method of laying line contributes to more rapid progress when bends are required, if the wrinkle bending method is being employed. Being already on skids, the pipe may be bent quickly using the tractor and other equipment of the stove-piping gang. Welders are on hand to apply the required heat. The bend can be made in a single joint at the exact required point in the line before being attached to the pipe already welded. This eliminates lifting a long section of welded pipe to make a bend, as in the firing-line method. If the required bend occurs close to one end

A. F. DAVIS

since his graduation from Ohio State University in 1914 with a degree of mechanical engineer in electrical engineering, has served The Lincoln Electric Company in various capacities—He was made vice-president in 1928 and secretary in 1938, and also serves on the board of directors—He is secretary of the James F. Lincoln Arc Welding Foundation, created in 1937 by the directors of The Lincoln Electric Company in honor of J. F. Lincoln, president of the company—Is a member of the American Welding Society, Sigma Alpha Epsilon, Eta Kappa Nu, and various local clubs and organizations.

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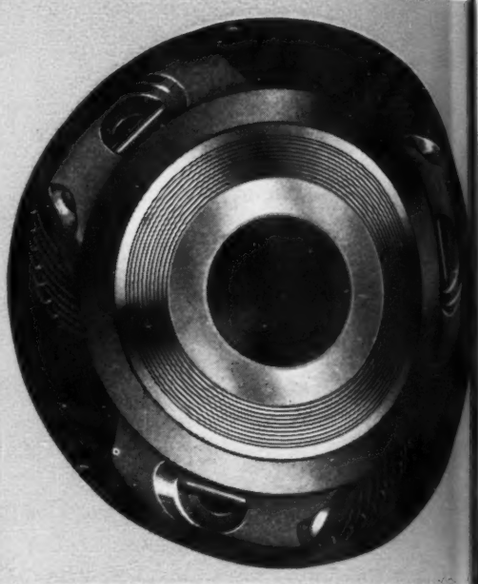

In this view looking down on the Sievers Reamer notice how the barrel-shaped cutters are in continuous contact with 30% to 35% of the circumference of the hole. This assures round, full-gauged walls!

A wheel (or cutter) rolling straight along a surface has essentially a rolling, not a cutting, action. Notice tendency to compress rather than displace excess material.

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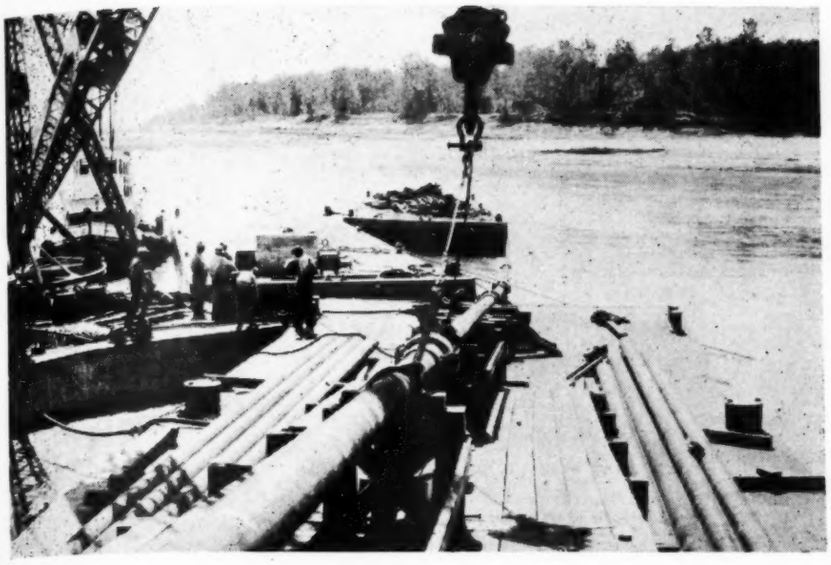


Lowering-in a 10-in. river line

of a joint, two joints can be quickly welded to obtain the desired leverage.

The usual procedure in the stove-pipe method is to line-up the pipe on skids high enough above the surface of the ground to permit making the welds entirely around the joints. Each weld is made individually, the pipe remaining stationary. The joint is tack-welded as the pipe is lined-up, following which the joint is finish-welded. All stove-piped joints are welded in three beads. Each bead on 6-in., 8-in., 10-in., and 12-in. pipe is welded with $\frac{3}{16}$-in. electrode, except the first bead in 6-in. and 8-in. pipe, the former sometimes being welded with $\frac{5}{32}$-in. electrode and the latter with $\frac{7}{32}$-in. The spacing between the pipe ends is $\frac{1}{8}$ in., whether the pipe is of 6-, 8-, 10-, or 12-in. diameter.

Speed of welding by the stove-pipe method averages four welds per hour on 6-in. pipe, three welds per hour on 8-in. pipe, two welds per hour on 10-in. pipe, and one and one-half welds per hour on 12-in. pipe.

The conventional firing-line type of construction was employed on five lines totaling 307 miles in length. These lines were a 24½-mile gas line for the Ohio Fuel Gas Company, a 54-mile gasoline line for The Great Lakes Pipe Line Company, a 136-mile oil line for the Continental Oil Company, a 39½-mile gas line for the Northern Natural Gas Company, and a 53-mile gas line for the Mountain Fuel Supply Company. Particulars of these lines are given in Table 2.

One centralized crew lines-up the

TABLE 1

Pipe lines constructed by "stove-pipe" method in 1938*

Length, miles	Size of pipe, in.	Cargo	No. of welds	Owner	Type of joint
18	8	Oil	2249	Pure Oil Company	Plain end, no ring
12	8	Oil	1498	Illinois Pipe Line Company	Plain end, no ring
11	2, 3, 4, 6, 8, and 12	Oil	1134	Carter Oil Company	Plain end, no ring
12	8	Oil	1211	Illinois Pipe Line Company	Plain end, and ring
75	8 and 10	Oil	8990	Central States Pipe Line Company	Plain end, no ring
8	6	Oil	966	Magnolia Pipe Line Company	Plain end, no ring
23	6	Oil	2733	Central States Pipe Line Company	Plain end, no ring

*Data from H. C. Price Company, Bartlesville, Oklahoma.

TABLE 2

Pipe lines constructed by "firing-line" method in 1938*

Length, miles	Size of pipe, in.	Cargo	No. of welds	Owner	Type of joint
24½	16	Gas	4728	Ohio Fuel Gas Company	Plain end, and ring
54	6	Gasoline	6996	Great Lakes Pipe Line Company	Plain end, and ring
136	8	Oil	16136	Continental Oil Company	Plain end, no ring
39½	16	Gas	2646	Northern Natural Gas Company	Plain end, and ring
53	18	Gas	6729	Mountain Fuel Supply Company	Plain end, and ring

*Data from H. C. Price Company, Bartlesville, Oklahoma.

Recommended spacing for pipe

Size pipe, in.	Average spacing, in.
Firing-line roll-welding using no liner	
4	1/8
6	1/8
8	1/8
10	1/8
12	1/8
Firing-line roll-welding using liner	
14	5/16—7/32
16	5/16—7/32
18	5/16—7/32
20	5/16—7/32
22	5/16—7/32
24	5/16—7/32
"Stove-pipe" position-welding using no liner	
6	1/8
8	1/8
10	1/8
12	1/8

Average speeds for shielded arc-welding

(Based on data obtained from welding of more than 720,000 joints in 100 different oil and gas lines under all sorts of conditions of terrain, weather, etc.).

Size pipe, in.	Average welds per hr.
Firing-line roll-welding using no liner (three beads)	
6	5.0
8	4.0
10	3.5
12	3.0
Firing-line roll-welding using liner (two beads)	
6	7.0
8	6.5
10	5.0
12	4.5
14	4.0
16	3.5
18	2.5
20	2.3
22	2.15
24	2.0
Position-welding using no liner (three beads) ("stove-pipe" method)	
6	4.0
8	3.0
10	2.0
12	1.5

pipe and welds the joints in stove-piping. In the firing-line method one crew lines-up the pipe, a second tack-welds the joints, and a third completes the welding; thus, the finish-welding crew works independently in completing the welds. As a result, the welding speed obtained is greater than when the stove-pipe method is employed. Using backing-up rings, joints on the firing-line may be made at an average rate of seven welds per hour on 6-in. pipe, six and one-half welds per hour on 8-in. pipe, five welds per hour on 10-in. pipe, and four and one-half welds per hour on 12-in. pipe. When firing-line welds are made without using backing-up rings, the welding speed is somewhat slower, averaging five welds per hour on 6-in. pipe, four welds per hour on 8-in. pipe, four and one-half welds per hour on 10-in. pipe, and three welds per hour on 12-in. pipe.

An interesting procedure has been in the combined use of stove-pipe and firing-line construction. On lines constructed partly through rough, muddy, or rocky country and partly through open, level country, this combined method of construction is used to excellent advantage. Under adverse conditions the stove-pipe method demonstrates its economy; in flat, open country, the firing-line method is advantageous because of its fast welding speed. The result of this combination of methods is fast welding when possible and maximum economy when conditions prevent fast construction.

A new type of engine-driven arc-welding machine was used on some of the 1938 pipe-line construction projects. This new welder, manufactured in 300- and 400-amp. sizes, is a Diesel-engine unit developed by Lincoln engineers in coöperation with manufacturers of Diesel power plants.

Development of the Diesel-engine-driven arc-welder brings the economy of Diesel operation to pipe-line welding. Fuel costs are reduced 33 to 86 percent, depending upon the price of the fuel oil used. At full-load operation, the Diesel welder uses 1½ gal. of fuel oil per hour.

Recommended sizes of electrodes for pipe-line welding

Size pipe, in.	Stringer bead, in.	Second bead, in.	Third bead, in.
Firing-line roll-welding using no liner			
4	5/32	3/16	1/4
6	3/16	3/16	1/4—5/16
8	3/16	1/4	5/16
10	3/16	1/4	5/16
12	3/16	1/4	5/16
Firing-line roll-welding using liner			
6	3/16—7/32	1/4—5/16	
8	7/32—1/4	1/4—5/16	
10	1/4—5/16	5/16—3/8	
12	1/4—5/16	5/16—3/8	
14	1/4—5/16	5/16—3/8	
16	1/4—5/16	5/16—3/8	
18	1/4—5/16	5/16—3/8	
20	1/4—5/16	5/16—3/8	
22	1/4—5/16	5/16—3/8	
24	1/4—5/16	5/16—3/8	
Position-welding using no liner ("stove-pipe" method)			
6	5/32—3/16	3/16	3/16
8	5/32—3/16	3/16	3/16
10	3/16	3/16	3/16
12	3/16	3/16	3/16

Arc-welding backing-up ring into pipe end

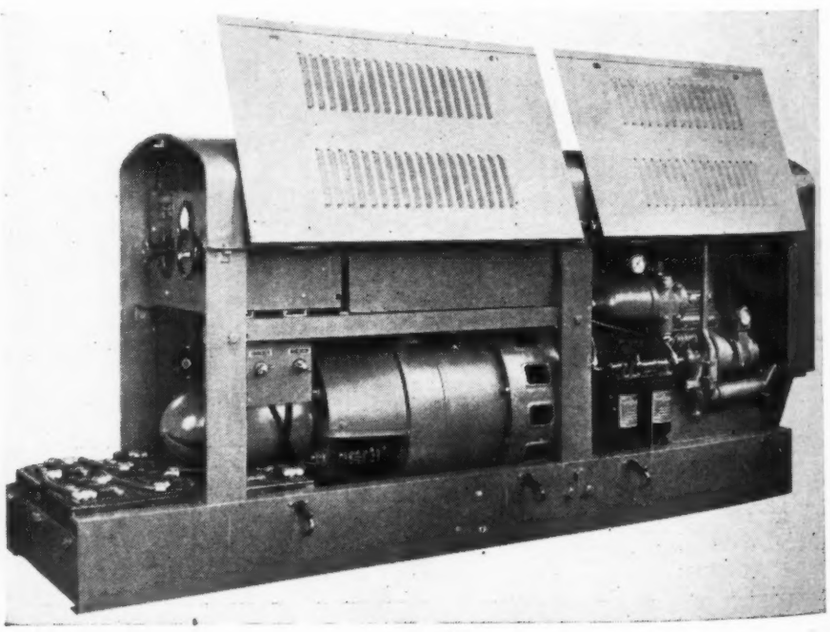
Recommended amperage and voltage for various size of rod

Diam. rod, in.	Amperage*	Voltage
Flat welding		
1/8	100—150	30—40
5/32	125—200	30—40
3/16	150—225	30—40
7/32	175—300	30—40
1/4	200—325	30—40
5/16	250—400	30—40
3/8	350—500	30—40
Vertical or overhead welding		
1/8	100—150	25—40
5/32	125—200	25—40
3/16	125—200	25—40

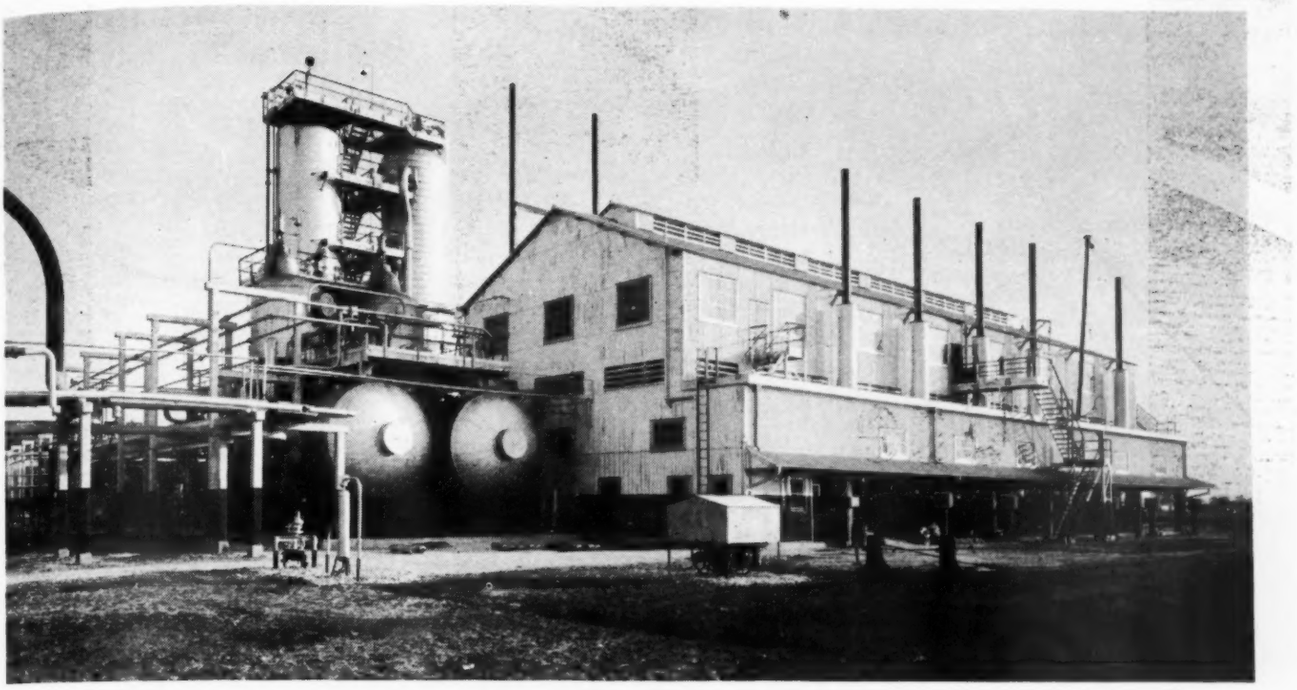
*Current should be about average of values shown.

Lb. of electrode per weld

Size pipe, in.	Using liner	Using no liner
6	1.0	1.25
8	1.5	1.75
10	1.8	2.25
12	2.0	2.5
14	2.3	....
16	2.6	....
18	3.0	....
20	3.5	....
22	5.1	....
24	6.0	....



Diesel-engine-driven arc-welder



Propane deasphalting and dewaxing plant showing large filter building, twin horizontal batch tanks, and propane receivers

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

Trends in Lubricating Oil Manufacture

By GEORGE F. FITZGERALD

PERHAPS the most outstanding feature in oil refining today is the desire to modernize. Most refiners have kept abreast of the times with respect to processing developments. They have made every possible comparison of the various methods available and have evaluated the results in terms of their individual problems. The object has been to make an intelligent choice before making a large investment.

This inquiring attitude has resulted in benefit to all refiners and particularly to the makers of lubricating oils. The sound facts that have been accumulated have encouraged the adoption of the new solvent extraction and solvent dewaxing processes. New and better filtering media likewise have come into use as a result of thorough research. Methods so adopted have, in almost every instance, given better results than anticipated.

The current rapid transition to new refining methods, although justified by the results, introduces many problems. Changes in operating technique can, in general, be mastered by existing plant personnel but the rigid control required calls for additional supervision. In dewaxing and extraction processes optimum conditions must be established and maintained. Otherwise losses of valuable oil and quality may put the process in the red. On the other hand, oil of the proper grade must be produced in sufficient volume to fill requirements. Most urgent of all problems, however, is the righ rate of obsolescence. Keeping up with current progress in processing equipment is essential but it calls for large capital outlay. It is estimated that for each refinery employee the total plant investment averages $46,000.

Of the various refinery products it is interesting to note the relative position occupied by lubricating oils. In the accompanying table approximate figures are shown indicating the relation between the quantity of lubricating oil manufactured and the total crude throughput. The introduction of cracking in 1920 resulted in so much additional low-grade crude being converted to gasoline that the lube production ratio declined from 12 percent in 1910 to 1.0 percent in 1938. As will be shown, this trend is expected to show a slight reversal in the near future.

Manufacturing economies and improvements in quality now possible have given the motoring public vastly superior lubricants at regular prices. Automotive lubricants are mentioned particularly because the automobile industry provides the greatest market for lubricating oils. Without this market the oil industry would not have grown so rapidly nor reached its present size. This mutual dependence is evident in the great extent to which research and development work in both fields is carried on coöperatively.

TABLE I

Production of lubes from total crude runs to refineries

	Lube in percent of total crude oil throughput
1890	6.5
1900	9.5
1910	12.5
1920	5.0*
1930	1.5
1938	1.0

*Effect of cracking begins.

Influence of Changed Automotive Design

Changes in automotive design have had profound influence, first, on motor fuel quality and, second, on motor oil quality. The development of the fast,

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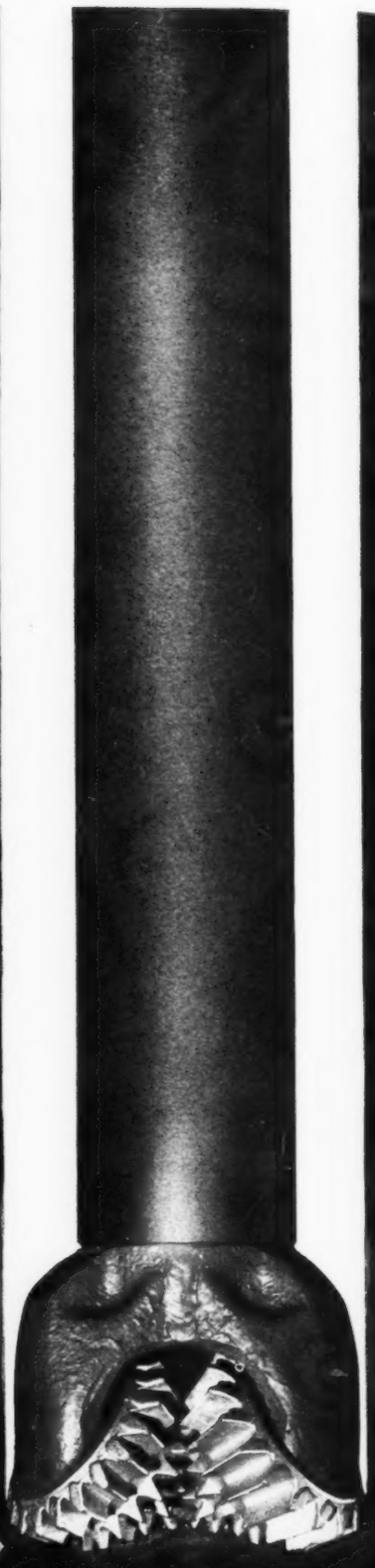

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light-weight car of great endurance called for immediate changes in lubricating oil specifications. The new close clearances of all moving parts made a lighter-bodied oil essential. Higher speeds and compressions and the accompanying higher temperatures made it necessary to develop oils of greater stability. The all-year operation of these new cars places emphasis on temperature-viscosity relationships as well as on fluidity characteristics as indicated by cloud- and pour-point tests.

The increasing demand for motor oils to meet these rigid requirements is largely responsible for the current extensive construction program in the refining industry. Modernization became the keynote of all refinery activity early in 1938 and seems certain to continue through 1939. The solvent methods for extraction and dewaxing are receiving the greatest attention. Improved vacuum distillation methods for making distillate lubes of heavier viscosity are becoming prominent. Bauxite and the new activated earths for color treatment are attaining increased importance.

The success of solvent methods is greatly dependent upon the application of instrument control.[1] In several recent installations the instruments and control valves represented almost ten percent of the total cost for materials. In dewaxing and extraction operations each unit in the process must function perfectly or the entire system becomes disorganized. Such coördination is possible by using the newly developed control instruments. They contribute to uniformity of product, labor saving, low solvent losses, and smooth operation. In extraction plants instruments are necessary to maintain proper oil-solvent ratios and levels of raffinate and extract solution in towers or settling tanks. In dewaxing, ratio-flow controllers are also invaluable. To accommodate a wide range of charging stocks, these controllers are equipped with interchangeable orifices. The control of flue gas for blanketing wax filters has recently been improved by using controller-actuated valves in both inlet and outlet flue-gas lines. Formerly control was obtained by using a circulating blower and a multiple-diaphragm, low-pressure gas regulator.

Benzol-Ketone Process

In solvent dewaxing, the benzol-ketone process represents almost two-thirds of the total installed capacity in the world.[2] This process employs a mixture of benzol (oil solvent) and either methyl-ethyl-ketone or acetone (wax anti-solvent) to which 5 to 10 percent of toluol is added to lower the freezing-point of benzol.

The wax-distillate or other charge is dissolved in this solvent mixture and forced through scroll-type chillers. Refrigeration in the first group of chillers is obtained by exchange from the dewaxed oil solution and in the second group it is obtained by direct expansion of ammonia. The chilled solution is then fed to continuous rotary filters in which the wax is separated and washed with solvent. Both vacuum and pressure filters are in use but the present trend is in favor of the former except for propane dewaxing. Because of the low solubility of wax in the solvent mixture at the filtering temperature, wax removal is substantially complete. The differential between the resulting pour-point temperature and the filtering temperature is small—15 to 20 degrees. The cloud-point of benzol-ketone dewaxed oils is almost as low as the pour-point, hence these products possess additional sale-appeal. Wax and oil streams leaving the filters are both carefully stripped of all solvent, which is then returned to the system. Distillation problems were the greatest obstacle to early commercial success and it is in this field that many of the recent refinements have been made. Each new installation profits by the experience gained from its predecessors. It is not surprising, therefore, that centrifuge dewaxing plants are being replaced as rapidly as conditions permit. Only recently in the Pennsylvania area a benzol-ketone unit having a capacity of 4400-bbl. per day was placed in operation as a replacement of a centrifuge plant damaged by fire. This unit embodies several refinements that reduce materially the cost of operation.

The Propane Process

The next leading solvent dewaxing method is the so-called "propane process." It differs from the benzol-ketone process in that it employs only one solvent—liquid propane. Furthermore, it offers a means of accomplishing deresining either in steps or simultaneously with dewaxing. This dual function affords the refiner certain of the benefits of solvent extraction in addition to dewaxing. In processing Pennsylvania oils it has been found[3] advantageous to remove only about 4 percent of resins. The removal of this small percentage of high-viscosity material has a twofold effect. It reduces the net viscosity of the total lubricating product, thereby reducing the amount of neutral oil required to obtain a miximum "yield" of SAE 10 and 20 motor oils. These lighter grades are now in greater demand than the SAE 30 and 40 grades that were popular a few years ago and, consequently, neutral oils are at a premium and the refiner is hard-pressed to balance his bright-stock production and his neutral-oil production. The de-resining operation materially improves this situation by removing the high-viscosity resins. As these removed materials are also very dark-colored, filtering yields are in some cases increased 100 percent. The saving in percolation costs is almost enough to pay for the propane plant in a nominal period of time. Obviously, the removal of resins and waxes increases the quality of the finished motor oils by increasing the resistance to gum- and sludge-formation and making them free-flowing at low temperatures.

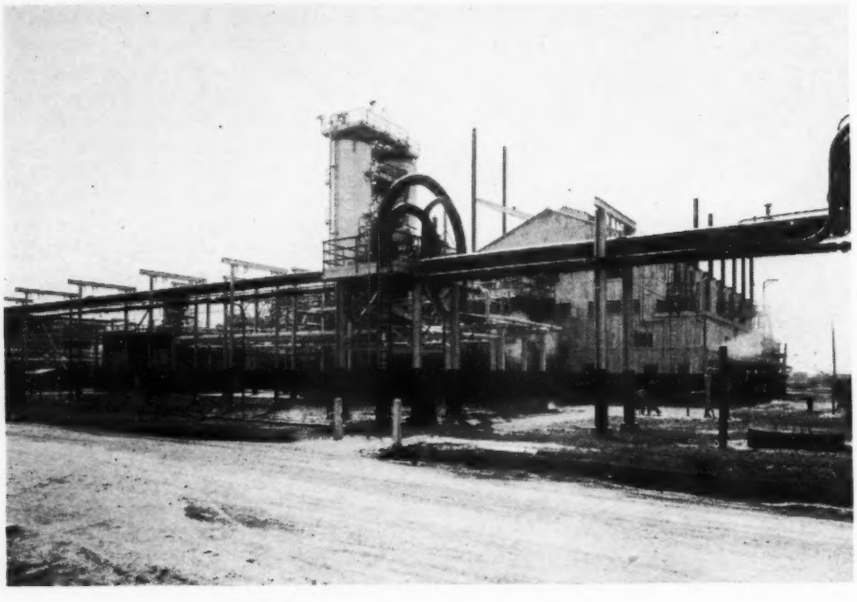
Regardless of the particular method used, solvent dewaxing permits the rapid, economical removal of the paraffin-waxes and petrolatums that cause oil solidification at low temperatures. Using these methods, maximum yields of lubricating oils of zero pour-point are readily obtained. Both distillate and residual stocks can be processed to the desired pour test with a minimum loss of oil to the wax. Waxy cuts from almost all types of crude have been successfully taken. These benefits accrue not only to lubricating manufacture but to the paraffin-wax and petrolatum departments because of more uniform, higher quality stocks. The slack waxes are lower in oil content and easier to sweat than slacks produced by cold pressing. Petrolatums likewise are drier and of lower penetration.

Solvent-extraction processes for refining lubricating oils are without question the outstanding recent contribution of chemical engineering to the petroleum industry. Based upon the ability of various solvents to dissolve or precipitate selectively certain components in hydrocarbon oils, these processes have revolutionized motor-oil manufacture. The statement by Pennsylvania refiners that highly paraffinic oil is the best lubricating stock was accepted in some quarters only after many years of controversy. Since about 1930 this question of quality has become one of more than just academic interest. Paraffinic-type oils were found to be the only kind capable of giving superior service in the high-speed, high-compression motors then appearing for the first time on the market. The demand for paraffinic crudes soon exceeded the supply. Solvent extraction has restored the balance by making premium quality oils available from mixed-base and naph-

[1] Thornton and Whipple, *National Petroleum News*, p. R171, May 3, 1939.

[2] Smoley, *Refiner and Natural Gasoline Manufacturer*, p. 536, November, 1938.

[3] McCluer et al., *Refiner and Natural Gasoline Manufacturer*, p. 635, December, 1938.



Another view of the propane de-asphalting and dewaxing plant. Note the maze of overhead piping and the pumphouse in the left background

thenic crudes. Solvent extraction and dewaxing together have made possible the utilization of many crudes that could not previously be refined into lubricants. This conservation of crude supply by more efficient utilization represents an enormous saving to the industry. It is because of these processes that we may expect to see the reversal of trend in the ratio of lube-oil produced to total crude runs. As mentioned, the volume of lubricating production now represents only 1 percent of the total crude oil processed. The increased volume of crude, of course, has been processed in topping and cracking operations. As the solvent methods are applied to crudes formerly undesirable as lubricating stock, the relative position of lubricating oil production will improve.

Types of Solvent-Extraction

The individual refiner's choice of solvent-extraction methods may be made from five principal types. In order of present installed capacity they are: Furfural, Duo-Sol, Phenol, SO_2-Benzol, and Chlorex. Furfural leads with 30 percent of the world's extraction capacity but is followed closely by the next three. Chlorex installations number approximately one-fourth as many as those of Furfural. The conditions of operation of these extraction processes differ widely. Temperature, solvent to oil ratio, rate of throughput, and percent of extract are dependent not only upon the solvent used but also upon the type of oil to be processed and the degree of refining desired. Furfural owes much of its popularity to the normal temperatures used in extraction[4]. The entire range of crude oils from highly paraffinic to naphthenic stocks can be processed between 150°F. and 250°F. For this reason the method is particularly adapted to the refining of waxy stocks. The solvent itself is very stable and can be readily removed from extract- and raffinate-solutions by steam distillation.

Proper operating procedures have been established for virtually all types of oil and the leading solvent processes are represented in refining plants throughout the world. The amount and type of extract material to be removed depends, of course, upon the particular crude. For paraffinic oils the removal of 5 to 10 percent of low-grade components improves the viscosity index number (viscosity-temperature relationship) by about one number for each percent of extract. Viscosity index tables were formulated upon a basis of 100 for highly paraffinic oils. This value can be raised by solvent extraction to 110-115 with nominal losses. Improvement beyond this, however, results in a marked reduction in yield because of the extreme difficulty of removing small residual amounts of low viscosity-index material. In the case of highly naphthenic oils a much greater proportion is extracted but the economic loss entailed is relatively less, based upon crude oil costs. In general, higher viscosity-index values can be obtained commercially by the solvent-refining of the superior paraffinic oils but it is practicable and desirable to produce oils of improved quality only from other types of crude. Without these additional sources the supply of premium lubricating oil for present-day motor cars would be inadequate.

The basic improvement in quality resulting from solvent refining has finally been recognized by aviation experts. When these oils were first offered for aviation purposes the response was negative. It was explained that only pure paraffinic lubricants manufactured by conventional methods were suitable for aviation oils. Improvements in processing and exhaustive research have now convinced airplane builders and pilots that solvent-treated oils have greater oxidation-stability and are less likely to form gum and carbon. The aviation market absorbs only a small part of the total volume of lubricants produced but it is definitely high-grade business. The refiner who is in position to meet aviation specifications has a very strong sales argument for use in other fields. Competition for this market it, therefore, very active.

High-Vacuum Distillation

Another method of de-resining and de-asphalting employs high-vacuum distillation, using a close-cut petroleum fraction as "carrier". Cylinder stocks and bright stocks may be run to less than 2 percent bottoms. Extremely high viscosity distillates and low penetration asphalts can be obtained by this process. According to Smoley, de-resining and de-asphalting of certain oils can be accomplished more economically in this way than by solvent methods. The improvement in obtaining a lower carbon residue in the distillate lubes is reflected in substantially increased filter yields.

The decolorization of motor oils has always been and perhaps always will be a major problem to the refiner. It is not inconceivable that a process may be developed for producing finished colors either by solvent extraction, by precipitation, or by molecular rearrangement. At present, however, even the best refining processes must be supplemented by the use of clay or activated earths in some form for the removal of color. Until about 1930 Fuller's earth was virtually the only filtering medium of consequence. The increase in consumption of Fuller's earth closely paralleled refining expansion for a time. Since 1933 refining capacity has continued to grow but Fuller's earth consumption has declined. A recent U. S. Bureau of Mines report shows a 24 percent decline in the domestic production of this commodity for 1938. This trend is affected

[4]Smoley, *loc. cit.*, p. 538.

NIXON GAS-LIFT SYSTEM

Will *produce from low fluid levels!*

Will *get all the oil!*

Fluid can be lifted more efficiently and more economically from all types of wells with the Nixon Surface Control Gas-Lift System. It will handle bottom hole flow from casing; also flow from open hole below casing.

It will completely exhaust the well, and do it without expensive changes or replacement. In many cases, the original installation will get all the oil.

BOTTOM HOLE FLOW

The illustration on the left is an intermitting system flowing from 15 feet off bottom. The flow valve is set just two feet above the packer. A special fluid chamber, set above the flow valve, quickly collects a full volume of fluid with a minimum of natural well pressure.

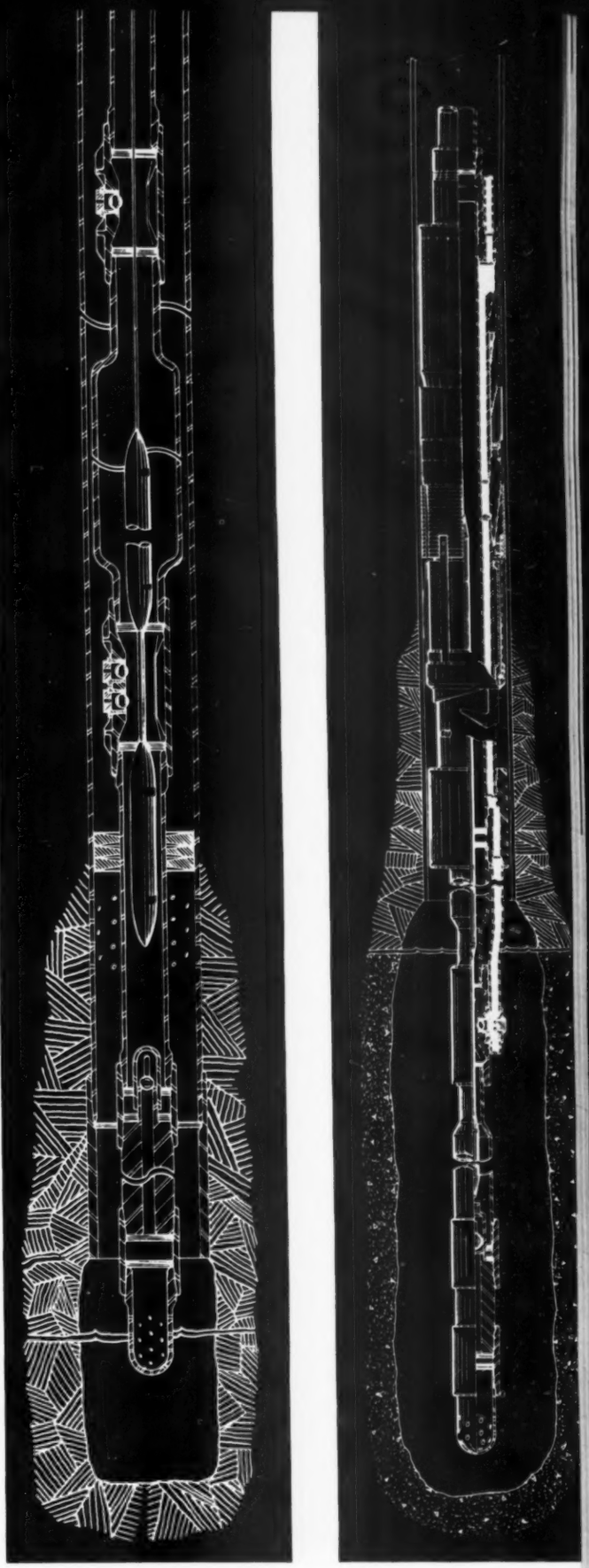
The special weight bar has a reduced section through flow valve, joining the long and short segments into which the bar is divided. The short segment opens the valve when raised, from below, into it. The long segment, above the valve, serves as a weight to push the short segment out of the valve and permit it to close.

Being mechanical and controlled from the surface, the operation of the flow valve is absolutely positive.

OPEN HOLE FLOW

The illustration on the right is a Nixon Gas-Lift producing from open hole below the casing. The flow valve is set in the tubing which extends below the casing into the open area. The packer is set just above the bottom of the casing. Fluid-raising pressure is by-passed through the packer directly to the flow valve. One or more valves can be run below packer if desired. A standing valve is in the end of the tubing to prevent pressure building up on the oil sand during flow period.

The packer is shown in a set position. The heavy white line indicates how fluid-raising pressure is by-passed through the packer to the flow valve.



In addition to these settings we are making numerous installations by running 1" and 1¼" tubing, with valves, inside of 2" and 2½" tubing, sealing off between the two strings when neccessary. With approximately 600 of these units now installed, we have yet to encounter a producing condition that could not be successfully handled.

High or low fluid levels, large or small volumes of fluid . . . all are handled at lowest cost and with greatest efficiency by the NIXON SURFACE CONTROL GAS-LIFT SYSTEM.

WILSON SUPPLY CO.

1412 Maury Street

HOUSTON » » TEXAS

by the relatively lower production of lubricating oils (See Table 1), the increased use of activated earths, and the introduction of bauxite. The efficiency of activated earths has been increased to such a degree that they can be continued in use much longer than formerly. Consequently smaller volumes per year are required to replace discarded material.

The use of bauxite has increased consistently. Numerous commercial installations are serving as laboratories in which operating data are being collected to supplement the statements of the suppliers and results have proved the real merit of bauxite for decolorizing and deodorizing neutrals, bright stocks, petrolatums, and waxes. Results obtained in the field are being used to establish optimum filtering temperatures, throughputs, burning temperatures, and rates. An impetus has been given to the study of filter washing techniques and their correlation with burning operations. Bauxite filtration is also being studied to determine the extent to which resistance to oxidation and emulsion formation may be increased by its use.

Decolorization combined with primary distillation has been the object of much experimentation and even more discussion. The research is based on the theory that the results of contact filtering could be obtained at a great saving in heat if the clay could be combined with the charge to the crude or re-run still and separated in the bubble tower. The original efforts were generally halted because of mechanical difficulties. Abrasion of tubes and bends was severe and in some instances the clay was carried upward in the tower and several trays plugged. Color removal, however, was excellent and the idea was never completely forgotten. The commercially successful application of this principle has recently been reported[5]. A portion of the charge is by-passed through a mixing tank where it is agitated with a weighed amount of clay. This slurry re-joins the main feed, is heated, first by exchange, then in the pipe-heater. On entering the vaporizer section of the bubble tower the hot, clay-treated oil is flashed to several side-cuts and a bottoms of bright stock viscosity is obtained. The clay drops down with the heavy bottoms thus prolonging the time of contact. Colors of all products are reported to meet shipping specifications. The new installation has facilities for close control of contact time and temperature, steam-stripping, and continuous filtering. Another feature is fully automatic clay-handling equipment. A totally enclosed, continuous rotary vacuum filter is used for removing the clay from the oil.

Recent developments that have created more difficult lubricating problems are illustrated by hypoid gear units and high-speed Diesel engines. Extreme pressure lubes containing sulphur, chlorine, or other activating agents are giving good service but further improvement is desirable. Research in the field is continuing and will doubtless lead to production of even better lubricants. Many people have had to discard the notion that a Diesel engine will burn any kind of fuel and, by inference, will run on any kind of lubricant. Diesel engine lubricants represent a relatively small gallonage to the refiner but to the research laboratories they have presented far greater problems than have ordinary motor oils. The Diesel engine operates at high temperatures and very high pressures and is usually expected to operate almost continuously. Evidence that lubricating oils capable of satisfactory service under these conditions have been developed is indicated by the steady increase in total installed Diesel hp. The use of Diesel-powered tractors in present-day gigantic construction projects was made possible largely by outstanding developments in lubricants. Diesel engines are now performing successfully in types of service previously thought impossible. The development of lubes especially designed for heavy service has made this possible. Severe service conditions make it necessary to select lubricants with the same care that is used in selecting steels and alloys.

New problems of this type are yielding to the combined efforts of those engaged in petroleum research and to equipment manufacturers. Coöperation of refiners and automotive engineers has in the past reduced many serious problems to a matter of routine. These successful experiences have served to strengthen the spirit of coöperation and to make it the dominant factor when considering new developments.

Chemical Composition

In the background of every discussion of lubricating oil quality is the question of chemical composition. For many years it was thought utterly to be impossible to identify the various components of petroleum. The laboratory development of solvent extraction, molecular distillation, and refractionation has made it possible to classify the types of hydrocarbons present in gasoline and lubricating cuts. This knowledge is essential to the proper selection and utilization of oils for specific purposes. It also leads to a reasonable basis for the correlation of laboratory tests with actual service runs.[6] A knowledge of the constitution of lubricating oil is a step nearer to an understanding of the mechanism of lubrication and thence to the synthesis of new and better lubricants. A practical application of this knowledge is evident in the comparison of propane with the usual selective solvents.

In propane de-resining, heavy resins are precipitated from lighter hydrocarbons, that is, separation is made according to difference in molecular weight. The other solvents separate one class of hydrocarbon from another, without strict regard to molecular weight. For example, chlorex separates naphthenes from paraffins. The enhanced value of the treated oils thus becomes a function of chemical constitution.

Catalytic Effect of Metals

Another subject of great importance to lubricating-oil refiners is the effect of metals in contributing to deterioration of the oils. Iron has been found to have the greatest catalytic effect on quality in storage and in service. Copper-lead bearings have some effect and silver-lead alloys have somewhat less. Recent studies[7] indicate that two-thirds of the oxidation and deterioration of oil in new engines is due to the catalytic effect of metals. Refiners are attacking the problem by searching for inhibitors to prevent this effect. Complex organic phosphorous compounds have been found valuable for this purpose. Other inhibitors are added to lower the pour-point, to prevent varnish formation and bearing corrosion, to increase oiliness, and to raise the viscosity-index. Many of these inhibitors could be synthesized using petroleum products as raw material. Naphthalene present in cracked gasolines can be condensed with chlorinated paraffin-wax to produce an effective pour-point depressor.

Most refiners would prefer to remain out of the chemical business and concentrate on the main objectives of fuels and lubricants. Synthesis of chemicals from petroleum on a large scale, although possible today, is not yet of sufficient economic importance to compete with established markets[8]. As necessity arises a compromise can probably be reached whereby the refiners would concentrate on the manufacture of synthetic lubes and supply raw materials to established chemical firms for further processing.

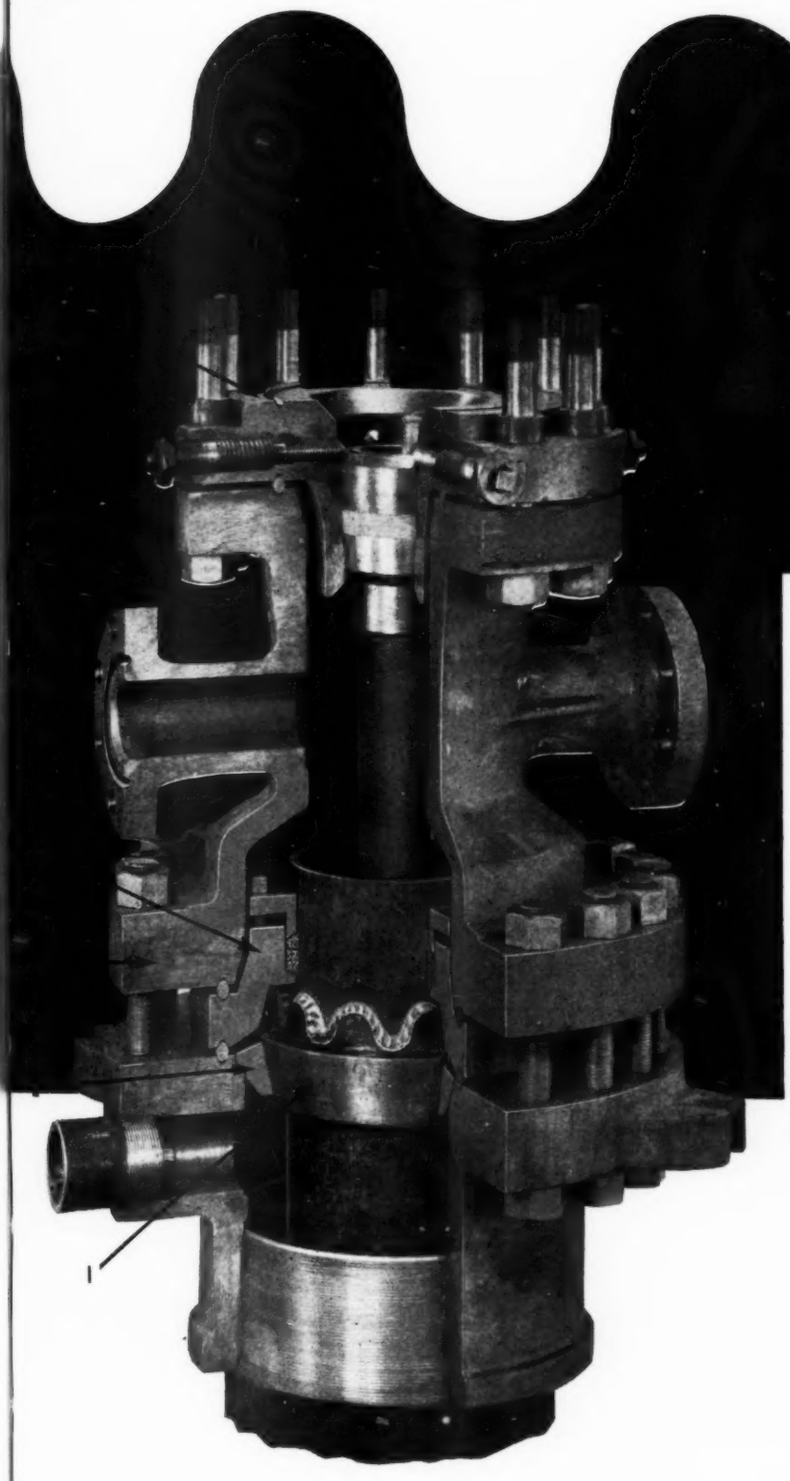
[5]Moore and Gwyn, *Refiner and Natural Gas Manufacturer*, p. 45, February, 1939.

[6]Varteressian & Fenske, *National Petroleum News*, p. R132, April 5, 1939.

[7]Downing, Holbrook, and Fuller, *National Petroleum News*, p. R129, April 5, 1939.

[8]Frolich, *National Petroleum Association*, Olean, N. Y., June 8, 1939.

WHY DID WE DO IT?



WHY was the welding method chosen?

Because welding is today an accepted and approved method, and has been found to be much stronger than a threaded and coupled joint. Through the use of the welding ring (1) instead of slips there is no slippage, wedging action, or tendency to collapse the pipe.

WHY is the welding ring scalloped?

In order to place more weld in shear and to eliminate any possibility of line concentration of stress.

WHY are A.P.I. ring joint flanges (3) used?

They are being accepted universally as standard because they afford the safest, most effective sealing means, and promote interchangeability.

WHY is the welding ring seat (2) used between the casing head body and the welding ring?

Because it insures quick, positive release of the casing from the head without cutting or damage to the casing and casing head.

WHY the independent packing gland (4)?

It is easy to install, is a time-proved pack-off method which assures a positive seal, and it avoids depending upon an untested weld to hold the pressure.

WHY is the Baash-Ross Type "W" Casing Head more economical?

Because it is compact and has fewer parts, requiring less expense attendant upon its installation.

WHY does the Type "W" Casing Head simplify running and setting the inner casing?

The inner strings can be run, landed, and cemented through the well control equipment; no special nipples need be cut in order to spot the casing at the correct depth; only a minimum of time is required for work in the cellar with connections and lines.

WHY is it unnecessary to overstretch the pipe when a Type "W" Casing Head is used, and what is the advantage of this feature?

With this casing head, tension is always maintained in the string. This feature prevents kinking and buckling the casing, loosening of the joints, and damage to the cement job. No overstretch is required to properly position the suspension members and make the weld.

WHY IS THIS THE LOGICAL TIME TO OFFER THE TYPE "W" CASING HEAD TO THE INDUSTRY?

Because casing manufacturers now produce low-carbon, high tensile strength casing especially made for welding purposes.

For complete details write to Baash-Ross Tool Co., 5512 Boyle Ave., Los Angeles; Houston, Texas; Oklahoma City; Export Office, 30 Rockefeller Plaza, New York City; or

SEE PAGES 169 TO 174 OF THE 1939 COMPOSITE CATALOG

BAASH-ROSS

Type "W"

CASING HEADS

P 615.635.4

Developments in Procedure for Installing Cathodic Protection to Pipe Lines

By WALTER F. ROGERS
Gulf Oil Corporation

AS the use of cathodic protection increases, the design of details for the proper application of this protective system is conforming more and more to engineering requirements and less to guesswork and rule-of-thumb methods. There is yet, however, much to be learned in connection with this subject. Fortunately, a sufficient number of the earlier installations were slightly over-designed so that the method had a fair chance to show its possibilities. Now that it has been demonstrated that electrical protection can be relied upon to prevent soil corrosion of pipe the matters of engineering design, selection of equipment, and comparative costs are being developed. The application of a protective system requires considerable knowledge, skill, and judgment for the results are good only if the method is properly applied. It is not, however, a cheap type of protection. Costs may vary from $100 to $2500 per pipe-line mile. To a company with several hundred or several thousand miles of pipe that might be so protected the total cost becomes a sizable figure. Costs averaging $100 per pipe-line mile are possible but seldom obtained. They are limited to lines that are laid with high-grade coatings that possess high electrical resistance. It is to be remembered that such coatings will have already required the expenditure of $800 to $1200 per pipe-line mile for material and application. This cost, together with the additional $100 per mile for cathodic protection, both comprise the total cost of preventing soil corrosion of the pipe. Installation costs for pipe having medium to poor coatings or no coatings at all are more likely to range from $500 to $2500 per pipe-line mile. To show the problems that confront the designer of an electrical protective system when a poor coating or no coating whatever is present it is interesting to follow the complete steps in such an undertaking.

WALTER F. ROGERS

was born April 3, 1905, at Tyler, Texas—Graduated from Tyler High School in 1922—Graduated from University of Pittsburgh with degree of B.S. in chemical engineering in 1926—Received professional degree in chemical engineering from University of Pittsburgh in 1933—Began work for Gulf Refining Company at Port Arthur in 1926—Transferred to chemical laboratory of Gulf Oil Corporation, Houston, Texas, in 1927 where he is still employed—Has specialized in studies of corrosion of production and pipe-line equipment.

Determining the Permissible Cost for Protection

The justification for authorizing the expenditure of money for repairs to a pipe line is usually based upon a record of trouble. On new lines in which no leaks have occurred but in which the management believes that rust holes are about to appear, the records usually are obtained from examination of line through the suspected areas or at uniform points along the line. These examinations may be in the form of bell-hole inspections, long-line current measurements, soil analyses, or other methods of testing. If, however, the line is of sufficient age to have suffered from corrosion in the past it is possible to predict with a fair degree of accuracy the need for repairs to the line. Pipe-line companies should keep, on strip-charts a complete record of all trouble and repairs of their pipe lines. One extremely handy and informative type of chart is shown in Fig. 1. The 15-year service record of 10 miles of pipe is shown, including basic data concerning soil types and general elevation of the line. To explain the symbols on the chart: the circles represent rust holes; the triangles, collar leaks; the dotted lines having figures above them depict the location and number of feet of pipe repaired by spot- or patch-welding. The symbols c_1, c_2, etc. represent the types of protective coating used when the pipe was repaired.

Inspection of the chart shows that with the possible exception of 2½ scattered miles the rest of the pipe contains enough "hot spots" to warrant repairs. The first thought is to take up the 10 miles of pipe, cut out the bad pipe, and coat the entire length with a coating of high-grade primer, one coat of enamel-type coating, and an outer non-deteriorating type of wrapping material. Based on costs for this type work the repair cost for this 10-mile section of 8-in. pipe at $2200 per mile would be $22,000. This repair job would usually result in 10 to 15 years of trouble-free service. In addition, by installing cathodic protection at the pump-station, focused on the pipe by means of an insulating flange at the station end and at the far end of the coating, the pipe can be cathodically protected at a total cost of about $800. The total cost of this job would be about as follows:

Installation Cost

1.	Repairs and coating	$22,000
2.	Cathodic protection	800
	Total	$22,800

Annual Cost

1.	Depreciation of repairs and coating, 5 percent	$1140
2.	Depreciation of cathodic protection system, 10 percent	80
3.	Executive overhead, taxes, etc.	400
	Total	$1620

It is possible by further study of the data in Fig. 1 to obtain an excellent idea of the probable future history of this line and the expected costs. A table should be prepared from Fig. 1 showing the age of the line by years and the cumulative rust-holes. These data can then be plotted on log-log coördinate paper as shown in Fig. 2. It will be noted that the data conform closely to a straight line. This type curve has been fully discussed elsewhere[1]. It is relatively safe to extra-

[1] "The Use of Rust-Hole Records to Study Pipe Service," by W. F. Rogers, A.P.I. Prod. Bull. 222, 1938.

polate this curve 3 years into the future. This has been done and the data obtained are given in Table 1. It is indicated that 71 rust-holes will develop in this line during the next 3 years. A previous article[1] states that the cost of repairs to an 8-in. line is $180 per rust-hole. Using this figure, $180 × 71 or $12,780 will be required to repair this line during the next 3 years, an average of $4190 per year. This predicted cost is sufficiently high to warrant making extensive repairs to the line. It is also obvious that it would not be out of reason to spend the $22,800 necessary to take the pipe up, coat it, and apply cathodic protection. Before spending this amount of money, however, it is advisable to consider the cost for cathodic protection alone.

TABLE 1

Cumulative rust-hole data
Line laid: Aug., 1924
Coating: None

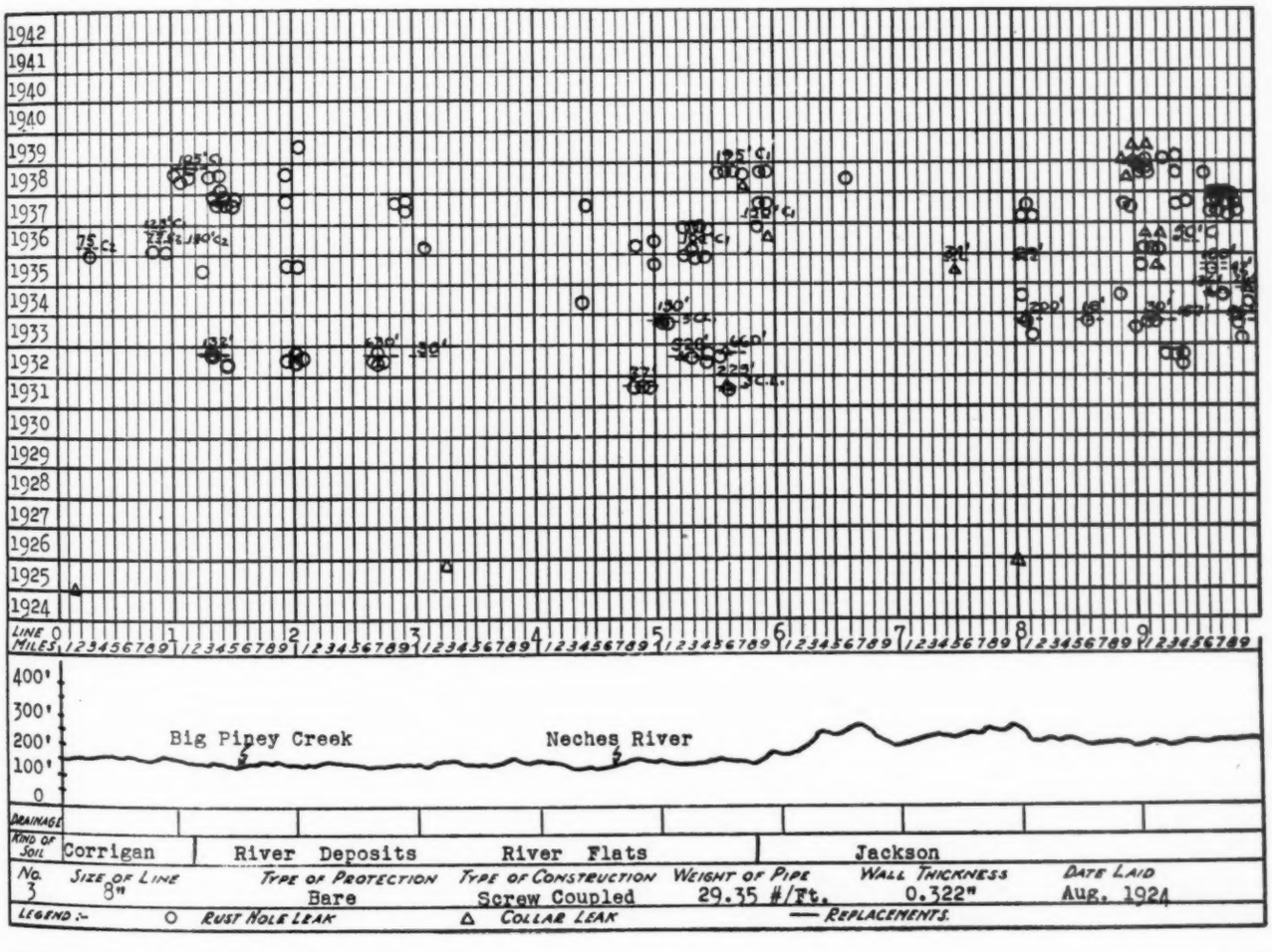
Year	Pipe age, yr.	Rust holes	Cumulative rust holes
1924	1	0	0
1925	2	0	0
1926	3	0	0
1927	4	0	0
1928	5	0	0
1929	6	0	0
1930	7	0	0
1931	8	4	4
1932	9	18	22
1933	10	10	32
1934	11	7	39
1935	12	10	49
1936	13	13	62
1937	14	33	95
1938	15	18	113
Predicted experience			
1939	16	13	126
1940	17	28	154
1941	18	30	184

Design Factors in Cathodic Protection

A. Criterion of protection. It was stated above that prices for reconditioning and coating pipe are sufficiently well known to make possible a rapid estimate of the cost involved in repairing any given quantity of pipe. This is not true at present for cathodic protection and a certain amount of field work will be necessary to determine the power requirements for the 10 miles of pipe shown in Fig. 1. The first question is, how much current will be required to protect this pipe? This in turn brings up the question, what shall be used as the index of corrosion prevention? At present there are two schools of thought on this matter. Most designers measure the potential in volts of the pipe to a copper sulphate electrode. The reading should be made with either a potentiometer or a high-resistance voltmeter, preferably the former. The trend has been to apply sufficient current to the pipe so that the reading of the pipe to the copper sulphate electrode is 0.80 volt. When this potential is reached it is assumed that the pipe is protected. It has been shown by Neely[2] that bare coupons attached to a well-coated line did not corrode appreciably when the pipe potential was 0.80 volt or above but that corrosion became marked when the potential fell below this figure. There is considerable uniformity of agreement among corrosion-prevention engineers about this value for well-coated pipe. When the pipe is bare or poorly coated this agreement no longer holds and it is advisable to examine this point more clearly. Fig. 3 shows the usual relative position of the pipe, contact bar, and copper sulphate electrode in making potential measurements of this type.

[2]Unpublished paper by V. L. Neely, presented at A.I.E.E. Symposium on Cathodic Protection, Houston, Texas, 1939.

Fig. 1. Rust hole-time chart



The resistance of the annulus between the pipe radius and the distance from the pipe center to the electrode may be calculated from the expression:

$$R = \frac{\rho}{2\pi L} \log_e \frac{r_2}{r_1}$$

in which

R = resistance, ohms.
r_1 = pipe radius, ft.
r_2 = distance from pipe center to electrode, ft.
ρ = resistivity of the soil in ohm-ft.
L = unit length, 1 ft. of pipe.
π = 3.14.

As a general rule the initial potential of a pipe to soil is approximately 0.45 volt. Then the change necessary to bring this potential to protection of 0.80 volt is 0.35 volt.

Using the formula E = RI and substituting,

$$E = \frac{I\rho}{2\pi L} \log_e \frac{r_2}{r_1}$$

the current I may be calculated.

The current per linear foot and per linear mile of bare 8-in. pipe necessary to give an increased value of E = 0.35 volt is shown in Table 2. In this case r_1 = 4 in. and r_2 = 16 in. It will be noted that for average Gulf Coast soil resistances, ranging from 1005 to 7600 ohm-cm., current requirements of 256 to 33.4 amp. per mile, evenly distributed, are required to give a measured potential drop of 0.35 volt. Three factors exercise an important influence in obtaining the 0.35 volt change. First, these soil resistance values used are for the soil at saturation; consequently as the soil dries out and the resistance increases less current is required to obtain the 0.35-volt potential drop. Second, during the first 24 hours of current flow the deposition of hydrogen on the pipe-surface will develop a higher pipe potential; this in turn allows the desired 0.35 volt increase in potential to be obtained by a smaller amount of current than is shown in Table 2. Inasmuch as many mucky corrosive soils have resistance values of 500 to 1000 ohm-cm. it is apparent from Table 2 that prohibitive currents of 256 to 527 amp. per mile would be required to change the potential 0.35 volt. In these cases the back e.m.f. of the deposited hydrogen may be 0.20 volt; this counter potential would decrease the current requirements to 109 to 14 amp. per mile. Third, in addition to the effects of varying soil resistance and polarization the pipe-to-soil potential will change seasonally. In general the pipe-soil potential will be lowest in the dry part of the year and highest in the wet part of the year. It is not uncommon to find in normal well-drained soils a potential change without current flow of 0.10 volt over the yearly period and for wet, mucky soils a potential change of 0.10-0.20 volt. Thus, in determining the current flow for a desired potential of 0.80 volt these factors must be considered:

1. The initial pipe-potential and its variation over the year of 0.10 to 0.20 volt.
2. The build-up potential obtained through polarization: 0.10 to 0.20 volt for bare pipe and 0.20 to 0.30 volt for poorly-coated pipe.
3. The potential drop of the current flowing through the annular soil section around the pipe. This will change with the moisture content of the soil.

At the present time and until further research shows the superior value of current-density measurements in low-resistance soils and waters over that of soil-pipe potential measurements, it is necessary to design on the basis of 0.80 volt as the minimum potential, to assure protection.

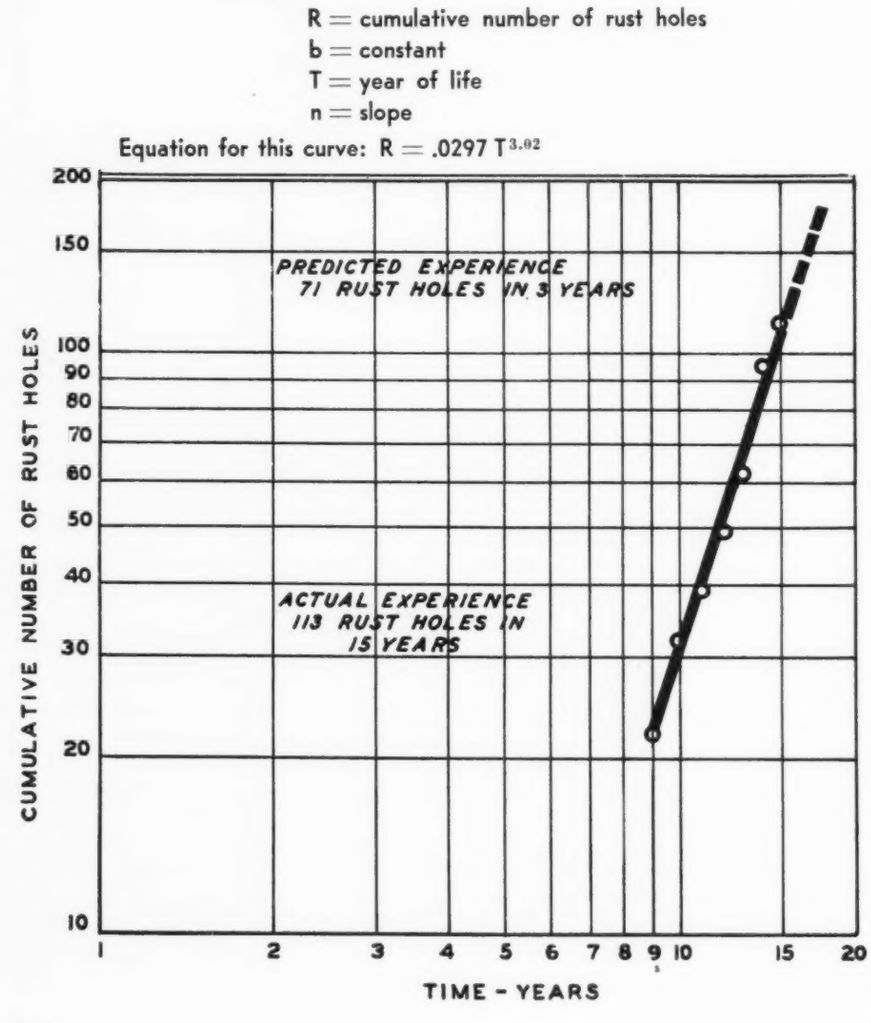
B. Welding-machine test. The usual method of determining the spread of current on a pipe and of determining the quantity of current necessary for a voltage of 0.80 is to use the d-c. generator of an electric-welding machine for the test. In the case of the 10 miles of bare pipe being checked, possibly three points along the pipe will be selected for test. At each

TABLE 2

Current requirements to give a soil-pipe potential drop of 0.35 volt without polarization effects

Soil corrosion		Amp. per linear ft. for $\Delta E = 0.35$	Amp. per linear mile
Ω-cm.	Ω-ft.		
487	16	0.0999	527
1005	33	0.0484	256
2040	67	0.0240	127
3050	100	0.0158	83.4
4570	150	0.0105	55.6
6100	200	0.0079	41.7
7630	250	0.0063	33.4
15250	500	0.0031	16.7
30500	1000	0.0016	8.3
152500	5000	0.0003	1.7

Fig. 2. Cumulative rust hole-time curve for estimating rust holes



PURPLE-STRAND *FORM-SET* ROTARY LINE

A choice of 3 centers

Hemp. This is the hard, tough core of hemp or other fiber that has been standard for many types of ropes for years. The core of Bethlehem rotary lines is specially lubricated with a compound that keeps the fiber pliable and resistant to moisture. This type of core is widely used in lines where highest strength and resistance to crushing are not required.

IWRC. For heavy loads, nothing can take the place of an independent wire-rope center. It adds to the strength of the rope. It greatly increases resistance to crushing and distortion, both on the drum and over the sheave. While the rope is stiffer to handle, it is just as flexible under load and because of its resistance to crushing it receives less damage in running over small sheaves than fiber-center rope. Bethlehem uses a specially designed wire rope as the center, an independent rope made just as carefully and with just as great precision as the rotary line itself. It carries its own specially compounded lubricant; in Form-Set line, the center is also pre-formed. Strands are accurately fitted around it to give full, adequate bearing surface. The cost is 15 per cent more.

Uni-Zact. Here is a core with proven advantage for rotary lines. It is a firm, smooth core made up of continuous flat strips of a parchment material, twisted into a uniform, continuous cylindrical center. It is more uniform in firmness and diameter than fiber. It gives better support to strands, thereby increasing life of the rope. Special lubricants make it water-resistant, rot-resistant and unusually tough. Experience has shown that a Uni-Zact core rotary line will often stand up on operations too severe for hemp-center line, yet the original cost is the same.

BETHLEHEM STEEL COMPANY

of these places a temporary ground of about two joints of 6-in. pipe will be buried. The negative side of the generator will be connected to the pipe line and the positive side to the 6-in. pipe ground. The maximum voltage of a machine of this type is about 40. The maximum current drain desired is 100 amp. although check tests at 50 and 25 amp. may be necessary. With 40 volts available the ground-bed resistance may be

$$R = \frac{E}{I} = \frac{40}{100} = 0.40 \text{ ohm.}$$

This resistance value can usually be obtained or one close enough so that 75 amp. can be developed by the welding machine. After the ground bed, welding-machine, and all connections are in place, a series of tests is made along the pipe to determine the initial pipe-ground potential. The welding machine is then started and the current adjusted to the desired value. Soil-pipe potential measurements are again made at regular intervals. It will be found that the potentials change rapidly at first and then in decreasing amounts until they become constant after about 18 to 24 hours. The difference between the initial and the 24-hr. readings is the voltage required to offset soil resistance and polarization. If the final readings are taken four or five hours after the start of the test a large part of the build-up will have been obtained and it may not be necessary to continue the test overnight.

If three welding machines can be used instead of one it will be found that the voltage increase due to the drained current will be larger than before. This is because as much as 25 to 50 percent of the current will be in the tapering-off part when the potentials are below protection value. When three welding machines are used this last 25 to 50 percent of the current is squeezed back into its restricted area.

In the area traversed by this bare pipe the soils have an average resistance at saturation of 5000 ohm-cm. One welding machine operating at 50 amp. will result in the following changes in soil potential for this pipe:

Distance from drain, ft.	Original pipe potential, volts	Pipe potential, (50 amp. drained), volts	Change in potential, volts
0	0.45	1.32	0.87
500	0.45	1.15	0.70
1000	0.45	1.01	0.56
1500	0.45	0.90	0.45
2000	0.45	0.81	0.36
2500	0.45	0.74	0.29
3000	0.45	0.68	0.23

These data show that protection potential is obtained 2000 ft. each side of the ground bed or 4000 ft. in all.

When the second and third welding machines are spaced 6000 ft. from, and on either side of the first, and all are operated at 50 amp., the pipe-soil potentials increase because the "tail-end" current from the first machine is squeezed back. In this case approximately 40 percent of the current is farther than 2000 ft. from the ground bed. The new relationships with three welding machines 6000 ft. apart and all operating at 50 amp. are:

Distance from drain, ft.	Original pipe potential, volts	Pipe potential, (50 amp. at each of three welding machines 6000 ft. apart), volts	Change in potential, volts
0	0.45	1.54	1.09
500	0.45	1.36	0.91
1000	0.45	1.17	0.72
1500	0.45	1.03	0.58
2000	0.45	0.91	0.46
2500	0.45	0.81	0.36
3000	0.45	0.74	0.29

If an additional polarization build-up of 0.05 volt can be expected, the potential of the pipe 3000 ft. from the unit becomes 0.79, or virtually protection potential. Also, the three welding machines operating at 100 amp. will create a protection potential 4500 ft. from the drain.

C. Effect of ground-bed spacing. Having determined the effect of the current spread from the temporary ground bed when placed 100 ft. from the pipe line, the designer might wonder if a better spread could be obtained if the ground bed were moved farther from the pipe. Tests have been made with different ground-bed spacings between 100 ft. and 500 ft. from the pipe. For data see Table 3.

TABLE 3

Effect of ground-bed spacing on pipe potential

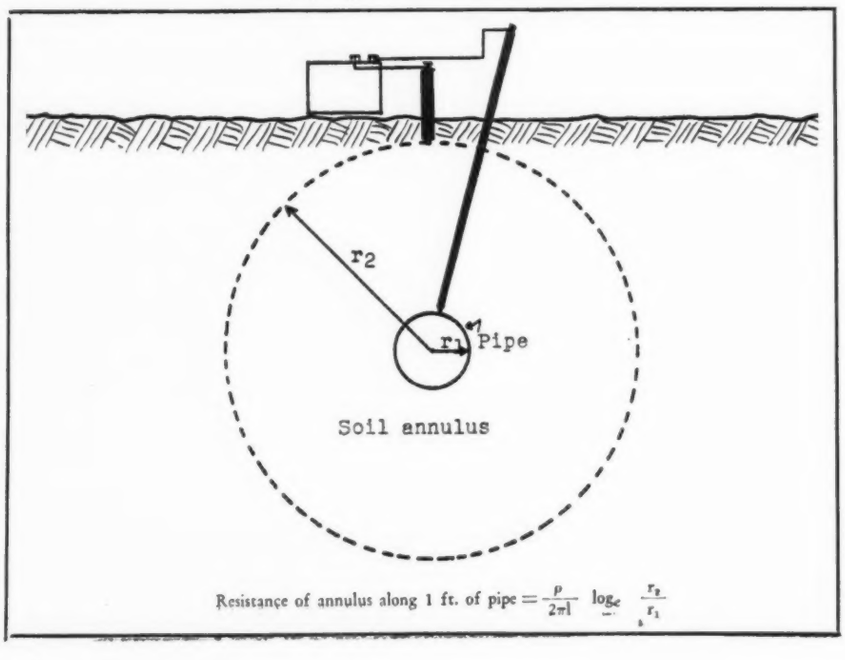
Distance from drain, ft.	Original pipe potential, volts	Pipe potential, (using ground bed 100 ft. from pipe), volts	Pipe potential, (using ground bed 500 ft. from pipe), volts
0	0.48	0.65	0.65
100	0.46	0.72	0.72
500	0.45	0.71	0.71
900	0.44	0.65	0.66
1300	0.44	0.56	0.56
1700	0.46	0.63	0.57
2100	0.45	0.56	0.57

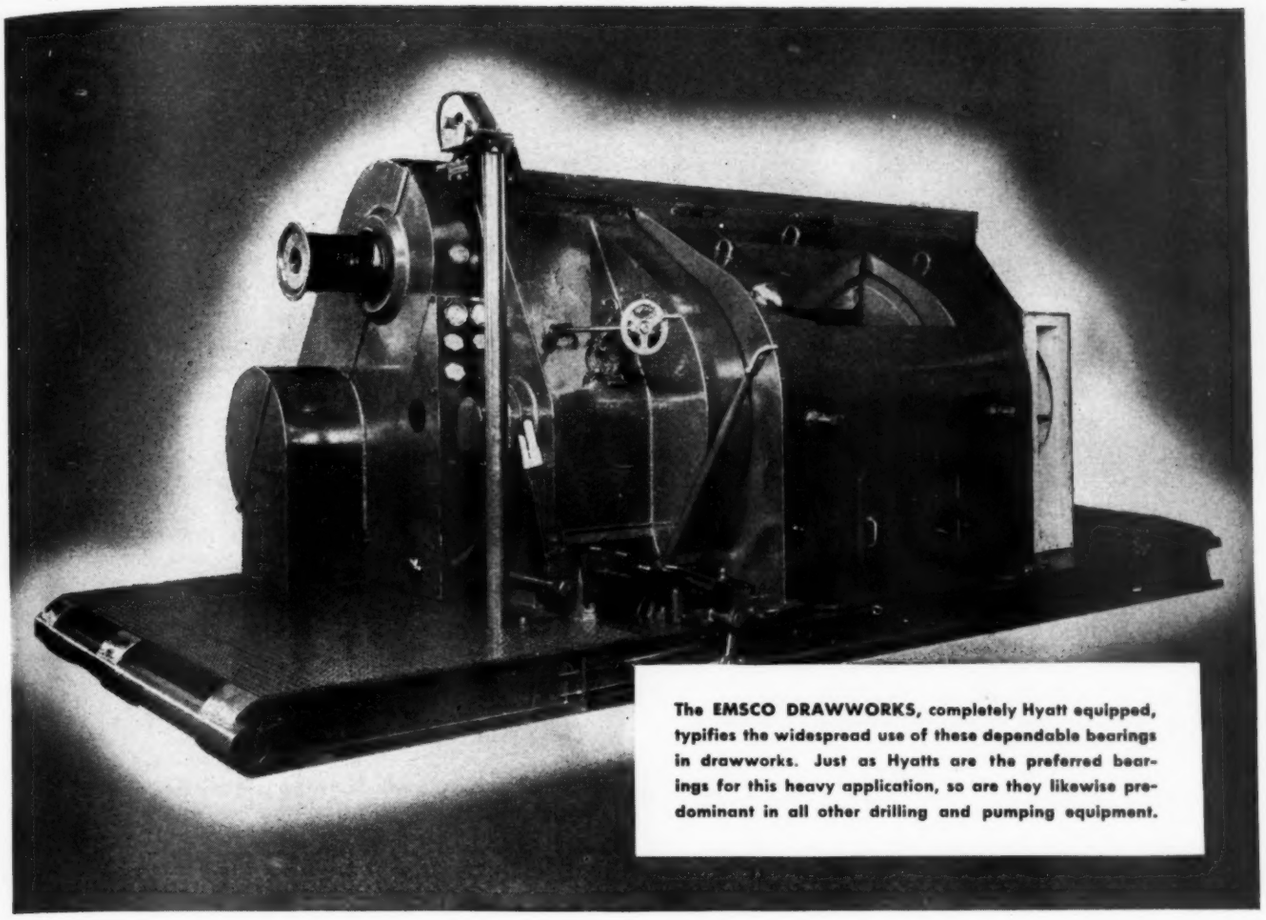
These data show that within the usual available distance for the ground bed of 100 to 500 ft. from the pipe that virtually equal current spread is obtained with either spacing. In the interest of economy regarding land ownership, poles, wire, etc., the ground bed can be placed only 100 ft. from the pipe to obtain satisfactory results. If extremely great distances back from the pipe of the order of 1 or 2 miles were possible the current would undoubtedly fan out more evenly. Such spacings, however, are impractical.

D. Ground-bed composition and resistance. Ground beds are usually composed of either carbon and coke or junk iron pipe. The latter has been used more extensively. Theoretically 18 lb. of iron per amp-yr. will be consumed. For a ground bed dissipating 100 amp., 1800 lb. of iron or 92.5 ft. of 19.45-lb. 6-in. pipe will be consumed annually. For a 5-year bed 92.5 × 5 or 462.5 ft. of pipe will be required.

The ground-bed resistance is the one

Fig. 3. Geometric relationship of pipe and copper sulphate electrode in making soil-pipe potential measurements





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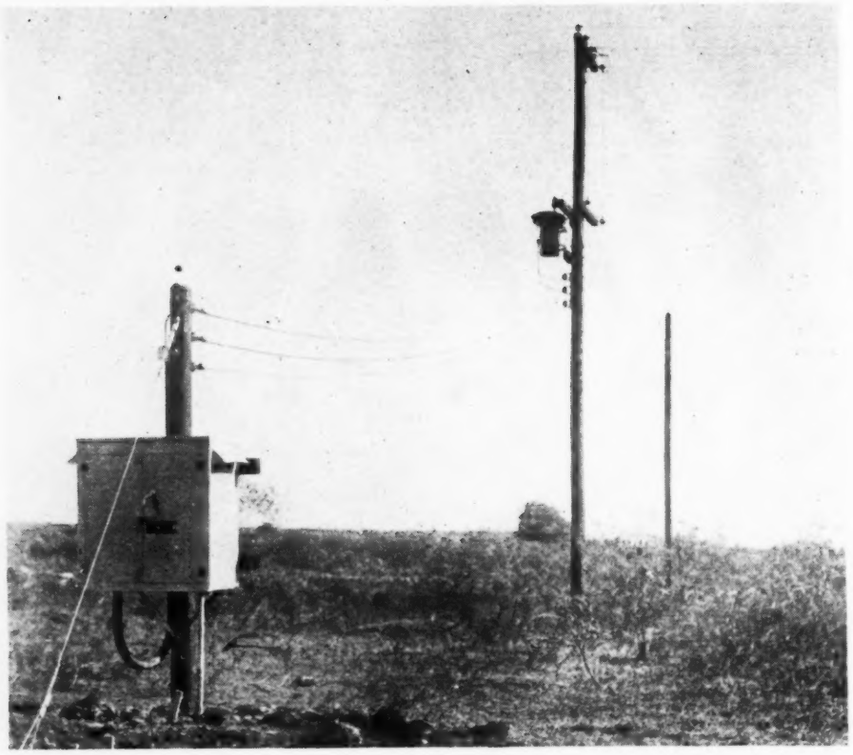


Fig. 4. Typical rectifier installation with transmission line and pole line to ground bed

unknown resistance of the d-c. circuit. If rectifying units of 10-volt rating are used, the overall circuit resistance must be cut to 0.10 ohm. If motor-generator sets or engine-driven generators are used the generator voltage is usually 20 volts and the ground-bed resistance need only be cut to 0.20 ohm. In most cases the pipe used in the ground bed is laid horizontally in 200-ft. lengths about 2 ft. below soil level and 10 to 20 ft. apart. If the proper ground-bed resistance is not obtained from the soil in its natural condition it must be heavily salted. Usually two to four tons of sodium chloride or calcium chloride must be plowed into the ground within a distance of 10 ft. on either side of the pipes to obtain a resistance of 0.10 ohm.

Calculating Cost of Protection

It is now possible to calculate the cost of the cathodic-protection installation. It is known that six 100-amp. units are required, spaced 9000 ft. apart. The voltage is to be 10 volts for rectifiers or 20 volts for motor-generator sets or engine-driven generators. Six ground beds, each comprising 400 ft. of pipe, are required. If rectifiers are used, 20 tons of calcium chloride will be required to lower the ground-bed resistance to 0.10 ohm. Copper cable (2/0 size) is used to connect the cathodic unit to the ground bed.

There are three possible systems to be considered for the generation of the power required for this job. These are: (1) wind-driven generators; (2) rectifiers using power supplied by a-c. generators situated at the pipe-line station and a transmission line along the pipe-line right-of-way, and (3) engine-driven generators situated along the right-of-way.

A. Wind-driven generators. These units in large sizes are usually rated at 40 amp. capacity. Such a mill on the Gulf Coast can be depended upon for an average output of 7 to 10 amp. This indicates six windmills per mile would be required. These mills complete with ground beds cost about $800 each. The initial cost for this type protection would be $10 \times 6 \times \$800$ or $48,000, which is, of course, not to be considered.

B. Rectifier units. An installation of this type will require a-c. power at the pipe-line station, a transmission line, and six rectifiers. The power required at 50 percent efficiency for the rectifiers and a 5 percent line loss is:

$$\frac{6 \times 10 \times 100}{0.50 \times 0.95} = 12.63 \text{ kw.}$$

The cost is:

1. A-c. generating equipment at $100 per kw.	$ 1300
2. Ten miles of 3-phase 5600-v. transmission line at $900 per mile	9000
3. Six rectifier units, 100 amp., 10 volts each, complete with ground bed, at $900	5400
Total	$15,700

Annual Cost

1. Depreciation on generating equipment and pole line, 5 percent	$ 511
2. Depreciation on rectifiers and ground beds, 10 percent	540
3. Power cost, $0.005 per kw-hr.	555
4. Overhead and maintenance	400
Total	$ 2010

These data show that the cost of installation is about 75 percent of the cost of repairing and coating the line but the annual cost is higher than that of the first method.

C. Engine-driven generators. These generators are supplied in 2000-watt, 20-volt capacity driven by an engine utilizing gas or gasoline fuel. The units alone cost about $700 each. Including house and ground bed the total installation cost is about $1200. The use of this equipment results in a higher annual cost than using rectifiers but the installation cost is less. The cost for this job is:

Installation Cost

Six engine-driven generators complete with house and ground bed at $1200 each	$7200

Annual Cost

Depreciation, 10 percent	$ 720
Overhead	300
Maintenance and fuel, $0.01 per kw-hr.	1050
Total	$2070

The cost for this system is $15,600 less than the cost of coating the pipe (including an $800 cathodic protection installation), and $8500 less than the cost of rectifier units. The annual cost is higher than the annual cost of the coated pipe but not sufficiently higher to warrant repairing and coating the pipe. There is also the possibility that future data may show less current is required, releasing some of the units for service elsewhere.

The use of engine-generator sets is the cheapest of the three possible cathodic installations and is, therefore, the system to be used.

Summary and Conclusions

The outline given here for installing cathodic protection follows the procedure now in use for designing these installations. Methods are changing constantly and a design system in use today may be obsolete in a year. Already plans are being developed in which soil resistivity measurements will play an important part in designing protection for bare lines. In addition, studies of minimum current density for protection rather than potential measurements are being made. It is expected that data published within the next 12 months will show an important addition to existing knowledge.

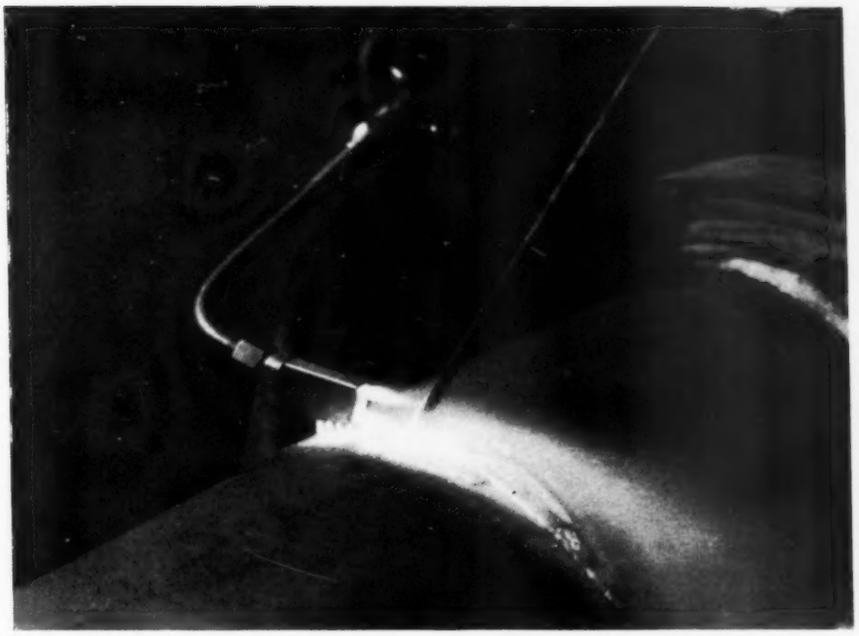


Fig. 1. Welding with a 6-flame bell-hole tip

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

By

F. C. HUTCHISON

Engineer, The Linde Air Products Company

Progress of Oxy-Acetylene Welding in the Petroleum Industry

A REVIEW of progress made in the pipe-line field during the last year indicates a number of major advancements in the oxy-acetylene process. These include continued success with the recently developed 4- and 6-flame welding tips and low-alloy-steel rod for welding pipe by the Lindeweld method, investigations into the subject of casing welding, the field stress-relieving of arc-welds, and the development and widespread acceptance of wrinkle-bending pipe.

Improvements In Welding Facilities

Of particular interest to the pipe-line operator should be a review of the comparatively recent development of a new 4-flame tip for bell-hole or position welding; a new 6-flame tip for double-jointing pipe and for roll welds, and a new low-alloy-steel rod.

The 4-flame welding tip, as the name suggests, consists of four separate flames or jets burning from a common head. Two small parallel flames are used to preheat the pipe ahead of the welding puddle, a third and larger flame preheats the welding rod, and the fourth flame accomplishes the actual welding.

Distribution of heat is extremely efficient using this new tip. The speed obtained on position welding is comparable to the speed obtained with the old type 3-flame tip on a roll-weld. No special technique is required for its use.

F. C. HUTCHISON

was born in Montreal, Canada, and received his elementary education in Minneapolis, Minnesota—After several years' experience in the manufacture of radio specialties, he entered Massachusetts Institute of Technology to specialize in machine design—Graduated in 1927 with the degree of bachelor of science in mechanical engineering—After graduation he was employed by The Linde Air Products Company—Spent two years in fundamental research work and then was transferred to the Apparatus Development Section—Since 1932 he has served as engineer in process service work—Lives in Kansas City, Missouri.

The 6-flame welding tip is similar in design to the 4-flame tip except that it has two additional preheating flames. Four flames preheat the pipe, a fifth preheats the rod, and the sixth accomplishes the actual welding. Because of the greater and more effective application of the heat, the 6-flame tip increases the welding speed on rolling welds, as compared to the speed obtained using the 3-flame tip, from 35 to 70 percent depending on the pipe size.

The development of the composition of welding rods has been with a view toward greater strength and ease of control in the welding operation. A new rod has recently been designed that results in tensile strengths 10,000 to 12,000 lb. per sq. in. greater than obtained from rods previously used in pipe-line welding, and yet retains sufficient ductility to meet all normal requirements. This rod has been developed for use with the new 4- and 6-flame tips for the welding of high-carbon pipe. In addition to its greater strength, it offers considerable resistance to over-heating in the molten state, and solidifies more rapidly. These qualities in the new rod permit easier control of the welding puddle, which in turn considerably increases the rate of welding.

Oil-Well Casing Welding

Modern casing pipe is of very high physical strength; the high strength being obtained by use of a high percentage of carbon or by the addition of certain alloying elements such as copper or manganese. These higher-carbon and low-alloy metals present two problems: (1) weldability, as the carbon is higher than the value considered in the past as an acceptable maximum, and (2) acceleration of the cooling rate of the completed weld without seriously injuring the structure and properties of both the weld metal and the adjacent base metal.

To date, welding of casing is still more or less in the experimental stage. Welding would be adopted more extensively if certain phases, both practical and metallurgical in nature, were solved and information made available concerning them. With this in view an extensive investigation of oxy-acetylene welding of casing has recently been made, covering not only the practical, economic aspects, but a metallurgical study of the entire problem as related to various grades of casing. This work has included experimentation in accelerating the cooling of the weld to expedite lowering the casing after welding, and the development of quench procedures that give the requisite physical properties of the joint without adversely affecting, metallographically, either the weld or the adjacent base metal.

Casing metals investigated. Three sizes of casings were investigated. These were 5-in. and 5½-in. O.D. by 0.304-in. wall thickness and 7-in. O.D. by 0.362-in. wall thickness. The chemical analysis for carbon and manganese is shown in Table 1. Two analyses were made of each of the various grades of casing used in the investigation.

TABLE 1

Chemical Analysis of Casing

Type of casing	Manganese, percent	Carbon, percent	Copper, percent
A.P.I. Grade B	0.56	0.24	....
A.P.I. Grade B	0.59	0.27	....
A.P.I. Grade C	0.87	0.41	....
A.P.I. Grade C	0.89	0.35	....
A.P.I. Grade C	1.27	0.49	....
A.P.I. Grade C	1.00	0.44	....
Low-alloy Grade C	1.03	0.23	0.45—0.70
Low-alloy Grade C	1.19	0.30*	0.45—0.70

*The carbon content of this specimen exceeds the specification figure of 0.25 percent.

Effect immediately following quenching. To determine accurately what hardness would be developed in different grades of casing under various quenching conditions, sections of unwelded pipe were furnace-heated to different temperatures and immediately water quenched. Table 3 shows the results of this study.

The average hardness curves for each quench method investigated are given in Figs. 2, 3, and 4. These curves give the Brinell hardness number in the weld and in the adjacent pipe material, and for comparison, the hardness of the base metal before welding.

Various methods of quenching investigated. Numerous methods of cooling the weld rapidly were tried, to determine their effects on the physical properties and the micro-structure of the joint. The first method of quenching was a direct water quench on the weld immediately following completion of the joint. Other methods of accelerating the cooling of the weld were investigated. These included in addition to water quench, a steam quench, air quench, and a copper-block quench, which are explained individually as follows:

Water Quench: Two ¾-in. hose were used to spray water on opposite sides of the weld at the hottest points until the metal was cooled below 200°F.

Steam Quench: Two jets of steam were directed on the weld at the hottest portions, until the metal was cooled below 500°F.

Air Quench: Two ¾-in. hose were used to direct air streams on the welds at the hottest portions until the metal reached black heat. A water quench was then used to reduce the temperature to 200°F.

*Copper-Block Quench:** The block, which will be described later, was clamped around the hot weld as soon as possible after completion of the joint. Water was then played on the lower pipe to draw the heat from the weld. When the weld had cooled to a black heat the clamp was removed and the weld cooled to 200°F. by water jets.

Samples for testing were taken from each weld, at least one specimen being taken from the finish zones, which were the hottest points on completion of welding. These specimens were given a metallographic inspection and tested for physical properties. All hardness readings were made with a Rockwell superficial hardness testing machine and converted to Brinell hardness number by the Rockwell Conversion Table. The hardness in the weld and in the adjacent heat-affected base metal

*Patent applied for.

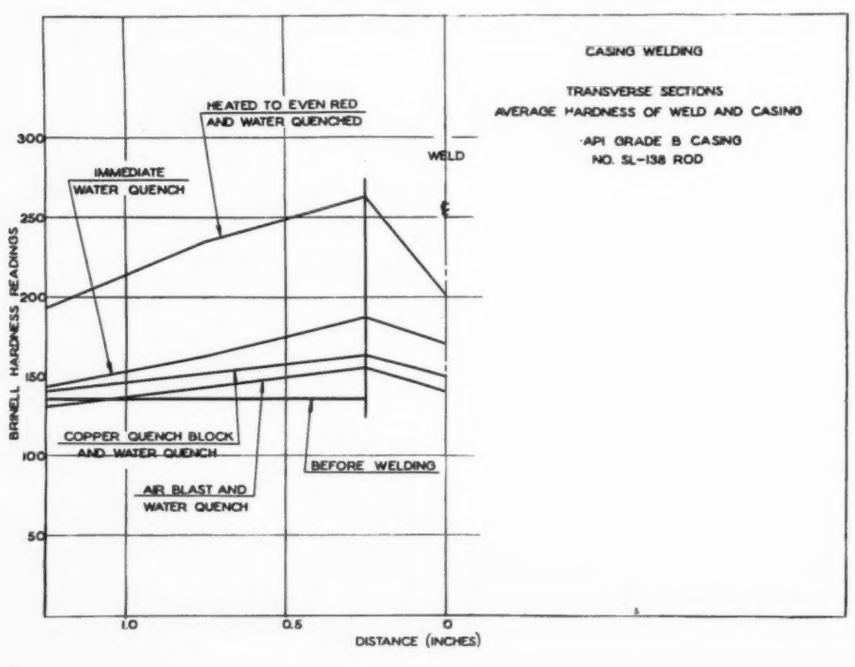


Fig. 2. Hardness curve—welding and quenching A.P.I. Grade B casing

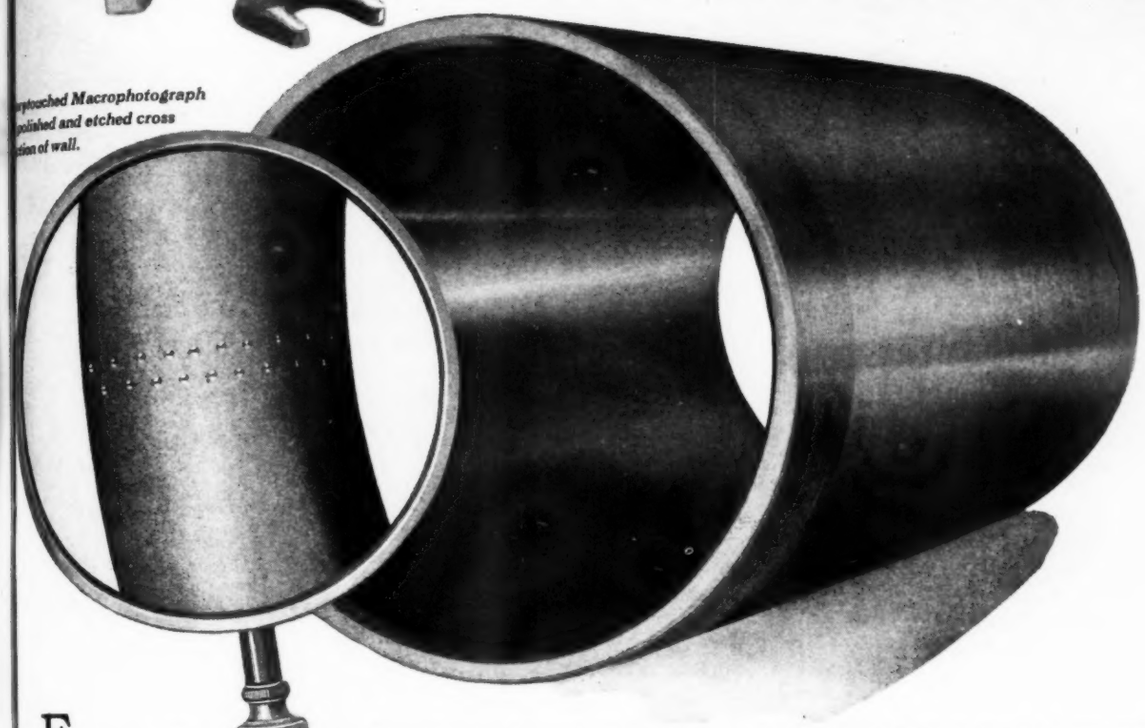
HARRISBURG

Announces the Nelson-izing Process

a great forward step in the making of Heavy Duty

PUMP LINERS

...ptouched Macrophotograph ...olished and etched cross ...tion of wall.



Rockwell "C" Rating	*Equivalent in Brinell Numbe*
24	248
24	248
24	248
24	248
25	253
25	253
25	253
25	253
31	293
34	321
36	341
38	363
41	388
48	464
51	500
57	578
58	601
60	627
60	627

For years, Harrisburg drop-forged seamless steel pump liners have set the standard for accuracy in diameters and threading, for smooth finish and dependability in service. Now the new and exclusive *Nelson-izing Process*—developed in the Harrisburg plant by Dr. T. Holland Nelson—produces pump liners of highest excellence • The outstanding features of the Nelson-ized liner are that by this new process, the *inner surface* can be raised—for almost any desired depth—to a *Brinell hardness as high as 625;* whereas the *outer surface* can be maintained, for any predetermined depth, with a *Brinell hardness of from 200 to 250* • No operation such as metal spraying, alloy insertions, case hardening or other surface preparation is resorted to. The physical properties and general structure of the material are maintained at the highest possible standard • Liners made by the Nelson-izing Process are unique in that they possess maximum hardness and wear-resistance where most desired, yet this is backed up with material in a tougher, more ductile condition. There is no sharp line of demarcation between the two. In the cross-section of the wall there is a combination of maximum hardness and toughness not obtainable by any other process • Patent covering the Nelson-izing Process has been applied for and assigned to the Harrisburg Steel Corporation.

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HARRISBURG STEEL CORPORATION

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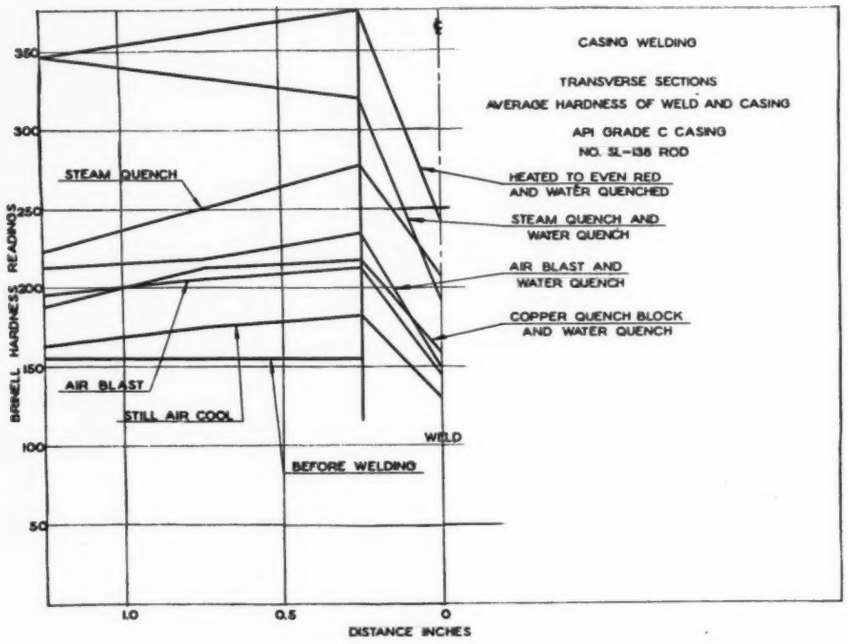


Fig. 3. Hardness curve—welding and quenching A.P.I. Grade C casing

is shown on the various accompanying curves.

It is to be noted that the highest hardness occurs not in the weld but in the base metal immediately adjacent to the weld. It is also to be noted that the hardness of both the weld metal and the heat-affected base metal is not very much higher than the original base metal when the copper-block quench was used.

Full-size tensile tests. To determine the physical strength of full-size joints subject to direct quenching treatment, tensile tests of full-size pipe joints were made using Grade B pipe. The pipe was 5½ in. O.D. having a wall thickness of 0.265 in. One of the joints was immediately water-quenched upon completion of welding, and the second one was given a treatment to accelerate the cooling by using a copper-block quench. In both cases the full strength of the pipe was developed in the weld; failure occurring about 1½ ft. from the weld. The yield was about 40,000 lb. per sq. in. and the ultimate tensile strength 60,000 and 61,000 lb. per sq. in. for the two joints tested.

A few other preliminary tests were made on full-size joints, which were cooled by the use of a copper-block to protect the weld upon being water-quenched. These preliminary tests did not disclose extremely high strength in Grade C casing inasmuch as the strength of the metals is not higher than 90,000 or 95,000 lb. per sq. in. The joint efficiencies, however, were better than 95 percent of the specified minimum tensile strength of the metal. These efficiencies are therefore much higher than obtainable using screwed, coupled casings.

Copper-block quench. The quenching procedure found most satisfactory for all types of casing used, including A.P.I. Grade C and low alloy Grade C, was a water quench using a copper-block to protect the weld. The recommended quench-block, shown in Fig. 5, consists of a heavy hinged copper body about 4 in. wide, grooved at the center to fit over the weld, protecting it for 2 in. on each side. A 12-in. skirt on the upper edge of the block protects the weld from any splashing of water that might run down over the top of the block and onto the hot area.

On completion of the weld, the two hinged halves of the block are fitted and help in position by a clamp. The assembly is designed to fit snugly around the casing at 1000°F. It is necessary to have a quench block designed for each different size of casing.

The quench block is assembled with the hinge and clamp situated between the two finish points so that the middle of each half of the block is over one of the hot finishing points.

Although the copper block conducts heat away from the weld, the greatest amount of heat is lost by conduction through the casing wall from the weld to the water-cooled area immediately below the block. The block is kept on the weld for a length of time varying for the different wall thicknesses of casing between 1 and 1½ min. On removal of the block, the water may be played directly on the weld for five to ten sec.

It was found, in general, that with the exception of Grade B pipe, the immediate water quench and steam quench were entirely too drastic and unsatisfactory for the weld, and particularly for the adjacent pipe material. The hardness resulting from these quench treatments was too high, indicating brittleness in the base material adjacent to the weld.

The only entirely satisfactory quenching procedures were found to be the air quench and the copper-block quench with water.

Multi-Flame Tip Development For Casing Welding

As an indication of the efficiency of the multi-flame tips, previously described, it might be stated that on heavy-wall casing the overall time per joint, using two operators, may be expressed in minutes equal to one-half the nominal diameter of the casing in inches. In other words, a 5-in. casing will require 2½ min. on the average, and a 7-in. casing, 3½ min. Even greater speeds can be obtained with light-wall material.

There has been in the past, when welding was not so generously accepted, some concern about the quality of the joint produced because of the so-called "human element." In multi-flame welding, the design of the welding heads and manipulative technique is such that consistent fusion can be obtained for 90 to 95 percent of the wall thickness through heat balance or equilibrium inherent in the preheating and fusion of the base

TABLE 2

A.P.I. Specifications for Physical Properties of Casing

Type of casing	Yield point, lb. per sq. in.	Minimum tensile strength, lb. per sq. in.
A.P.I. Grade B	35,000	60,000*
A.P.I. Grade C	45,000	75,000
Low-alloy, Grade C	45,000	75,000

*Because of the necessity for placing carbon limits on line pipe for welding, the physical properties of Grade B pipe are slightly lower than the Grade B material in A.P.I. Std. No. 5-A.

TABLE 3

Hardness of Each Grade of Casing Water-Quenched at Different Temperatures

Type of casing	Carbon, percent	Quenching temp., °F.	Brinell hardness number
A.P.I. Grade B	0.24	1600	212
A.P.I. Grade B	0.24	1700	241
A.P.I. Grade C	0.41	1500	600
A.P.I. Grade C	0.41	1600	600
A.P.I. Grade C	0.41	1700	600
Low-alloy Grade C	0.30	1500	418
Low-alloy Grade C	0.30	1600	387
Low-alloy Grade C	0.30	1700	340

metal, and in the preheating and melting down of the filler rod. With reasonable supervision, training and qualification of operators, an efficiency of 80 to 90 percent may be expected.

Stress-Relieving Welds in the Field

A comparatively new application of the oxy-acetylene blowpipe that may assume considerable importance in the future is that of "stress-relieving" welds in the field. When an installation is designed for extremely high pressures, subject to shock and vibration or a wide temperature range, good practice dictates that the weld be stress-relieved.

It has been found that certain types of this work can be effectively and economically stress-relieved in the field by an oxy-acetylene flame. A complete stress-relief will usually result from heating the metal to about 1200°F. and varying amounts of relief take place if the maximum temperature ranges downward. Insufficient work has been done on this problem to date to give a final and conclusive picture, although several applications have been entirely successful.

Wrinkle-Bending

Another interesting development in recent years in the field of pipe-line construction is the development of the practice of "wrinkle-bending." Wrinkle-bending is a modification of the creased bend and corrugated tangent that has, for some years, been used in the fabrication of steam power-plant piping.

The advantages of the wrinkle-bend are many and the saving in dollars to the pipe-line constructor is apparent, although sometimes difficult to evaluate. The wrinkle-bend may readily be applied on any sag-bend, over-bend, or side-bend, thereby replacing the conventional "cold" bend or "fire" bend that at one time were standard practices. Its use eliminates unwieldy equipment and the large portion of high labor cost incurred because of the need for a bending crew.

Wrinkle-bending has the further advantage of overcoming one of the main objections of the pipe-line constructor to the use of light-wall high-carbon pipe, as all types of bends may be made in the field, on such pipe, with the same ease that such a bend may be made on mild steel pipe. On the other hand, cold-bending of thin-wall high-carbon pipe is most unsatisfactory because such pipe is inclined to spring, without taking a "set," to such an extent that it may collapse.

The preparation of the wrinkle bend is comparatively simple and the procedure is essentially the same for all sizes of pipe. It consists in heating by a regular oxy-acetylene blowpipe one or more narrow bands of metal at right angles to the longitudinal axis of the pipe. The large capacity multi-flame blowpipe, designed especially for heating, is particularly adaptable to this work. On pipe of less than 6 in. in diameter one blowpipe supplies sufficient heat to prepare the pipe for bending. On pipe 6 in. in diameter

TABLE 4

Coupon Tests of Grade B Welded Casing Employing Water-Quench

Type of casing	Yield point, lb. per sq. in.	Tensile strength, lb. per sq. in.	Remarks	Joint efficiency, percent
With weld reinforcement				
A.P.I. Grade B	48,000	76,000	Failed in plate 2 in. from weld	126.7
A.P.I. Grade B	48,000	76,000	Failed in plate 2 in. from weld	126.7
With reinforcement removed				
A.P.I. Grade B	49,000	78,000	Failed in plate 2 in. from weld	129.9
A.P.I. Grade B	48,000	76,000	Failed in plate 2 in. from weld	126.7

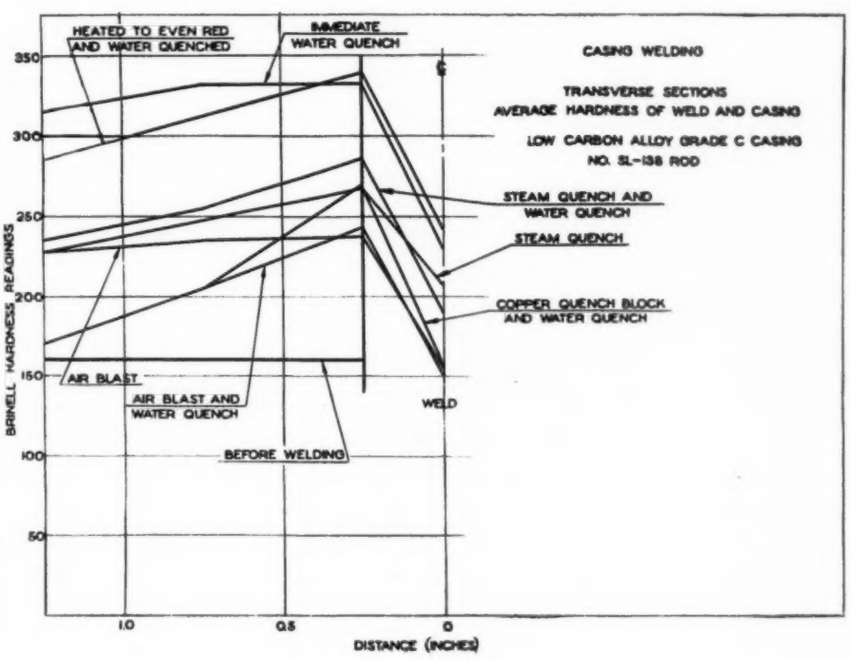


Fig. 4. Hardness curve—welding and quenching low carbon alloy Grade C casing

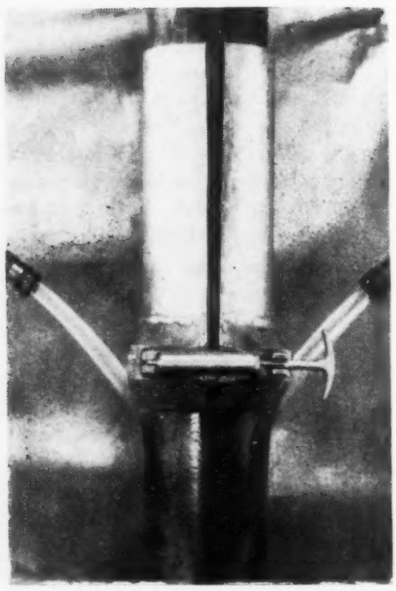


Fig. 5. Copper quench-block

and larger, a more satisfactory bend is made with the use of two flames, and on sizes 10 in. and above, 2-flame practice is essential. The band of heat should be 2 in. to 3 in. wide at the point of bending and should extend equidistant from the center until the heated band extends ½ to ⅔ the circumference of the pipe, tapering to a point at the termination of the heated area. The pipe should be heated to a bright red, at which temperature the "critical range" of the metal is reached and the pipe is not strained as in cold-bending. At this point the pipe is bent manually, by tractor, or by bending rig until the heated portion buckles sufficiently to give the pipe the desired bend.

Good practice would seem to indicate that a 5 deg. bend per wrinkle is a maximum and that a 2 to 3 deg. bend per wrinkle is better. The number of wrinkles indicated, therefore, is predetermined by the total degree of bend required. At no time during the process of making the bend, or afterward, should the pipe be artificially cooled or quenched. Should high-carbon pipe be artificially quenched, the bend or wrinkle may crack, due to sudden chilling of the metal. If possible, the spacing of the wrinkles should be at least one pipe diameter apart. This is, however, not mandatory, as 24-in. Grade "B" seamless pipe, having a wall thickness of 5/15 in., has been successfully bent approximately 28 deg. with 5 deg. wrinkles spaced 8 in. on center. Such practice should be followed only in special cases.

The advantages to be obtained from wrinkle-bending, on pipe lines or in station work, as compared to the conventional method of field pipe bending, can be summarized in part as follows:

1. Wrinkle-bending is the only satisfactory method of bending light-wall pipe.
2. It is the only satisfactory method of bending high-carbon pipe.
3. Mill-coated or yard-coated pipe may be bent in the field with far less damage to the protective coating, resulting in economic saving.
4. On pipe-line construction, when only occasional small-degree bends are required, such bends may be made by the same crew and equipment employed in the laying operation, without materially delaying the progress of the work.
5. Considerable excavation and time can be saved in rough country as the pipe can be readily wrinkled to fit almost any contour of the ditch rather than having to grade the ditch very carefully to fit the bend.
6. Of special importance from the engineering standpoint is the fact that the pipe wall opposite the bend is not thinned from its original thickness and at the point of wrinkling compression squeezes the pipe so that the metal is slightly thicker than the original wall. Furthermore, with this type of bend, the cross-section of the pipe receives no distortion provided the bend is properly made.
7. Wrinkle-bending adapts itself particularly well to the stove-pipe method of constructing pipe lines.

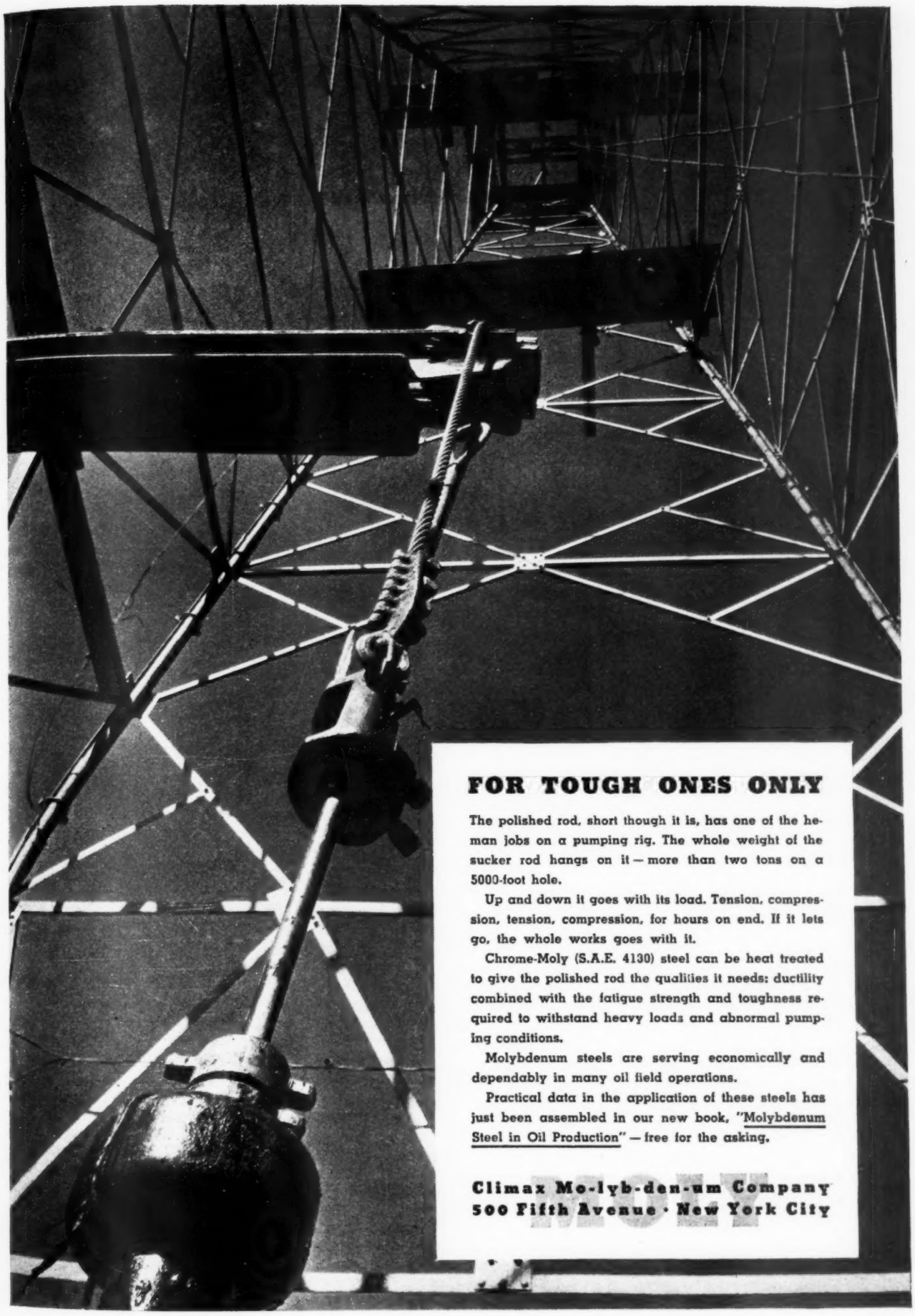
Fig. 6. Heavy-duty heating blowpipes facilitate the wrinkle-bending of overland pipe lines

TABLE 5

Coupon Tests of Welded Casing Employing a Copper-Block Quench

Type of casing	Yield point, lb. per sq. in.	Tensile strength, lb. per sq. in.	Remarks	Joint efficiency, percent*
With weld reinforcement				
A.P.I. Grade B	47,000	78,000	Failed in plate 2 in. from weld	129.9
A.P.I. Grade B	47,000	78,000	Failed in plate 2 in. from weld	129.9
A.P.I. Grade C	63,500	93,500	Failed in weld	124.6
A.P.I. Grade C	65,000	94,000	Failed in weld	125.4
Low-alloy Grade C	60,000	82,000	Failed in weld	109.0
Low-alloy Grade C	61,000	83,000	Failed in weld	110.2
With reinforcement removed				
A.P.I. Grade B	48,000	78,000	Failed in plate 2 in. from weld	129.9
A.P.I. Grade B	48,000	78,000	Failed in plate 2 in. from weld	129.9
A.P.I. Grade C	64,000	94,000	Failed in weld	125.4
A.P.I. Grade C	65,000	94,000	Failed in weld	125.4
Low-alloy Grade C	62,000	84,000	Failed in weld	111.5
Low-alloy Grade C	61,000	82,000	Failed in weld	109.0

*Based on specification of minimum tensile strength (see Table 2).



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Progress in the Manufacture of Butane

By J. W. VAIDEN, Manager and F. E. FISHER, Chief Chemist,
Natural Gasoline—Natural Gas Division, Skelly Oil Company

FOR a number of years the natural gasoline industry has witnessed a gradual and increasing growth in the demand for the lower hydrocarbons. Propane has become well established as a domestic fuel in the northern and eastern areas and its distribution has been extended to virtually every part of the country. The use of propane as a domestic and industrial fuel, however, has been somewhat handicapped by the high cost of distribution due to the high-pressure tanks and cylinders necessary to contain it.

The use of butane, for domestic or industrial fuel, burned either as an undiluted vapor or carbureted with air, has shown a very rapid increase within the last few years. The distribution of this product has been chiefly in the southern, southwestern, and western areas where atmospheric conditions are favorable to the use of simple batch vaporization, which is used in most of the domestic fuel installations. Due to the lower vapor pressure of butane, and the comparatively small cost of distribution, butane is in demand by many persons living outside the distribution areas of the natural and artificial gas companies. The cost in most cases is considerably less than that of propane.

Demand For Butane Has Increased

The demand created for butane by increased domestic and industrial use has led many natural gasoline manufacturers to enter the field of production of this hitherto unimportant hydrocarbon. In some few cases the production of gasoline has become almost secondary in importance to that of liquefied gases, particularly butane.

Polymerization and kindred processes, used commercially for only a short time, have increased the demand for butane to a much greater extent than was anticipated by even the most optimistic a few years ago. The greatest demand is, however, concentrated in small areas where butane can be made available to the polymerization plant at a relatively low cost because of low transportation cost. Probably the greatest market for butane as feed for polymerization plants is in East Texas where natural gasoline manufacturers are supplying large quantities of butane to refiners who are equipped with polymerization plants, through the facilities of a pipe-line system covering a considerable, but concentrated, area. Refiners in other sections of the country are installing, or have under consideration the installation of, polymerization plants, which will open a market for butane to the natural gasoline manufacturer who is so situated that he can deliver butane at a reasonable cost.

F. E. FISHER

after serving in the World War, joined the technical staff of the Chestnut and Smith Corporation, research organization devoted to problems of natural gasoline manufacture—Became affiliated with the research department of Phillips Petroleum Company six years later and was in charge of the Bartlesville laboratory of that company—In 1930 he left Phillips to enter the manufacturing business, and two years later entered the employ of the Skelly Oil Company.

A photograph and biographical sketch of Mr. Vaiden, co-author of this article, can be found in connection with another of their articles that appears in this issue of *The Petroleum Engineer*.

Unfortunately, the price that the refiner, or polymerization plant operator, can pay for butane and still make a profit from his operation is usually so low that only those natural gasoline manufacturers who can deliver to the refiner through pipe lines or other low-cost transportation facilities can expect to benefit from the demand. Although butane has been virtually a waste product of the natural gasoline industry for years, the problem of disposing of it at a profit is not so simple as it might seem.

Trend is to Higher Quality

The purchaser of butane, for domestic or industrial fuel, or for polymerization feed or other processing, has come to demand a specialized product, free to a considerable extent from contaminating lower and higher hydrocarbons, and of uniform quality. To meet these requirements the manufacturer has had to install additional equipment at his gasoline plant, and in many cases to revamp completely the plant for economical and efficient manufacture of the product. Although the greater yield and improved quality of the product will eventually pay, the competition from lower grade products of those plants not having the better equipment has handicapped the more progressive manufacturer who must show a profit on his costly investment in equipment. The trend is definite, however, toward a higher quality product and reliability of supply and has occasioned considerable interest in the design and construction of plants for the efficient production of high-purity liquefied gases at low cost.

The last few years have witnessed some very interesting developments along these lines. New plants have been constructed and older ones modernized for the express purpose of obtaining higher yields of propane and butane, and for isolation of the individual products. The methods used to obtain the desired results have varied somewhat, depending upon local conditions and the product required, but usually one or more of the following are used:

1. High-pressure compression.
2. High-pressure absorption.
3. Refrigeration.
4. Vapor rectification.

Many factors must be considered in the selection of the most desirable process. In an existing plant the changes in design or operation will usually consist of one or more of the following:

1. Increase in absorption or compression pressure.
2. Increase in oil rates in absorption plant.
3. Lowering of oil temperature.
4. Direct refrigeration under high pressure.

5. Vapor rectification of gas at low temperature.
6. High-pressure rectification of liquid product.

An increase in pressure is effective in increasing the recovery of the lower hydrocarbons, provided a sufficiently low temperature can be maintained to condense or absorb and retain the desired constituents. The plant equipment obviously must be suitable for operation at the desired pressures and means for adequate cooling must be provided. Due to the increase in the heat of absorption at the higher operating pressures, intercooling of the absorption oil is sometimes necessary. This may be done by double contact absorbers, or by internal cooling coils in a single absorber.

An increase in the rate of oil circulation through the absorber is effective in increasing the yield of the lower hydrocarbons at a given pressure, provided the oil can be maintained at an optimum temperature and can be effectively stripped in the distillation equipment. An increase in oil rate requires larger equipment throughout the plant and such an increase can seldom be obtained economically in the average plant.

Use of Artificial Refrigeration

As the water-cooled equipment has rather definite limitations, depending upon atmospheric conditions beyond the control of the operator, recourse must usually be had to artificial refrigeration to maintain constant operating conditions throughout the year. The use of propane or butane as a refrigerant offers to the natural gasoline manufacturer a readily available and efficient medium to increase the cooling in his plant to any desired point in a most economical and satisfactory manner, using equipment common to the manufacture of natural gasoline. The refrigeration is conducted in a closed cycle, exactly as when other commercial refrigeration mediums are used, such as ammonia. Compression is by standard forms of compressors as used for the compression of natural gas in gasoline recovery. Condensation and cooling is effected in the type of apparatus generally used for these purposes. Expansion of the liquid refrigerant is in a shell-and-tube cooler of usual design, in most cases the liquid refrigerant being vaporized in the shell of the cooler under controlled pressure. The vapors are returned to the compressor to complete the cycle.

The refrigeration thus obtained is applied at various points in the plant system. Absorption-oil temperature is reduced, usually to about 60° F. The entire system can be operated at any temperature necessary for efficient recovery of the desired product. In some cases, when the gas is of suitable composition, condensation of the marketable hydrocarbons can be effected by the application of refrigeration to the gas stream, either through heat exchangers and coolers, or by direct contact with cold brine and subsequent separation of the liquid hydrocarbons from the brine.

A plant designed by the M. W. Kellogg Company for the Duval Gasoline Company in South Texas operates under low temperatures and quite low pressures for the production of gasoline by refrigeration of the compressed gases. The gas stream is dehydrated before the cooling is effected. The designer asserts that this system can be extended to the efficient production of propane and butane by application of the proper pressure-temperature combination and that operating and construction costs are much lower than in the conventional design of plant.

The Humble-Hanlon interests in the East Texas field are processing the combined output of about 13,500 wells to produce approximately 400,000 gal. of butane and natural gasoline per day, obtaining a recovery of possibly 95 percent of the available butane. The plants operated by this group all have been arranged to obtain optimum recovery of butane and gasoline but identical methods are not used to effect the desired result. Combination high-pressure compression and oil absorption, or vapor rectification characterizes these plants, propane refrigeration being an important part of each process. Oil temperatures of 60° F. or lower are employed in the absorption system and appropriate oil rates are maintained. Double-contact absorption is used at one plant to minimize the effect of the excessive heat of absorption and to assure maximum contact at low oil temperatures. The combined product of the various plants is moved by pipe line to the Texas coast for final separation into the desired products such as natural gasoline, "bottled gas", and polymerization charging stock. As now equipped a recovery of propane as great as 40 percent is said to be possible should it be desired.

Various combinations are used in different plants when increased recovery of the lower hydrocarbons is desired. The arrangement of the plant, and the process used, vary with individual cases to suit the particular requirements. In general, however, the design follows along the lines mentioned above.

One fact is well worth noting with regard to those plants recently constructed. That is, the application of sound engineering principles and the careful selection of materials and equipment to meet the exacting conditions necessary for efficient extraction and rectification have taken the place of the haphazard construction methods that have been altogether too common in the past. The safe and efficient processing, storage, and transportation of highly volatile hydrocarbon mixtures require observance of high standards in every phase of the business. Every piece of equipment used in the construction of the plant must be studied carefully so that efficiency and safety may be obtained and yet maintenance and operating cost be not excessive.

Storage facilities for the high vapor-pressure products require the best in engineering design and construction. The behavior of hydrocarbon gases at high pressures and low temperatures sometimes leads to interesting problems, among which is the formation of gas hydrates in the presence of water or water vapor. Dehydration of the gas is therefore one of the problems facing the designer of a high-pressure, low-temperature plant.

Repressuring

Repressuring of oil and gas sands is increasing in importance. The design and construction of plants to recover the useful hydrocarbon constituents from the gas before it is returned to the sand requires a marked departure from standard practice.

In oil-absorption plants designed for the recovery of the lower hydrocarbons it has been found that the use of absorption oil of low molecular weight offers a considerable advantage and the use of such an absorbing medium is rapidly increasing.

As efficiency of cooling is an important factor the chemical treatment of cooling water is receiving greater attention. The volume of water lost by evaporation in cooling, together with wind and leakage losses, is considerable and the cost of water treatment is likely to become excessive unless a very careful study is made of the water, the treatment, and the conditions under which the water is used.

From an overall viewpoint, the design, construction, or operation of a plant for the production of butane or propane is little different from a plant for the efficient recovery of natural gasoline. The only practical consideration is that of the high volatility of the lower hydrocarbons and the precautions necessary in connection with the recovery of such product, their separation from the other recovered hydrocarbon mixtures, and their safe handling after recovery.

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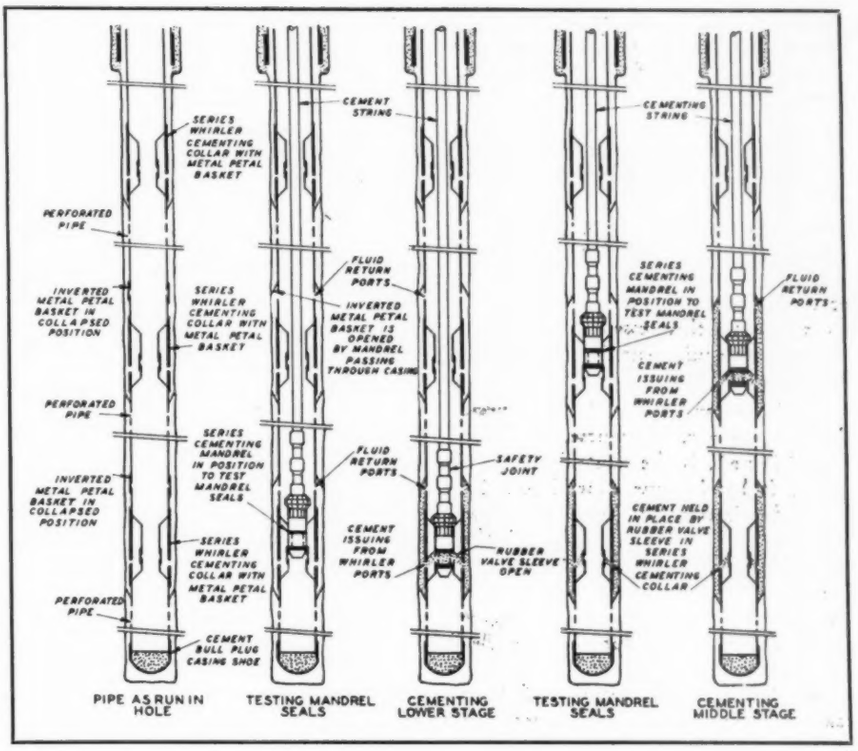
SERIES WHIRLER CEMENTING COLLAR WITH METAL PETAL BASKET
PERFORATED PIPE
INVERTED METAL PETAL BASKET IN COLLAPSED POSITION
SERIES WHIRLER CEMENTING COLLAR WITH METAL PETAL BASKET
PERFORATED PIPE
SERIES CEMENTING MANDREL IN POSITION TO TEST MANDREL SEALS
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CEMENT STRING
FLUID RETURN PORTS
INVERTED METAL PETAL BASKET IS OPENED BY MANDREL PASSING THROUGH CASING
FLUID RETURN PORTS
CEMENT ISSUING FROM WHIRLER PORTS
TESTING MANDREL SEALS
SAFETY JOINT
RUBBER VALVE SLEEVE OPEN
CEMENTING LOWER STAGE
CEMENTING STRING
SERIES CEMENTING MANDREL IN POSITION TO TEST MANDREL SEALS
CEMENT ISSUING FROM WHIRLER PORTS
FLUID RETURN PORTS
CEMENT HELD IN PLACE BY RUBBER VALVE SLEEVE IN SERIES WHIRLER CEMENTING COLLAR
TESTING MANDREL SEALS
CEMENTING MIDDLE STAGE

By

WALLACE A. SAWDON

Pacific Coast and Foreign Editor

Developments in Drilling Technique in California

ALTHOUGH no depth record has been established during the last year, the number of 11,000- and 12,000-ft. wells has increased in some of the San Joaquin Valley fields. In drilling to these depths, continued improvement has been made in both equipment design and drilling technique. Considerable advancement has been made during the last few months. Some of the work has been experimental, in preparation for the time when even deeper wells will be drilled. All advancements, quite noticeably the result of intelligent application of experience gained, not only provide for these future contingencies but also increase the efficiency of rotary-drilling operations under present conditions.

Probably the outstanding development in drilling technique in California has been the increase in rotating speed. This same statement was true a year ago; but whereas the maximum speed then was 400 r.p.m. or slightly greater, a rotating speed of 600 r.p.m. has recently been used in drilling at least one well. This high speed was mainly used in testing and was actually applied in drilling only a small amount of hole. Speeds of 500 to 575 r.p.m., however, were used consistently in this well in drilling deeper than 7000 ft. This particular well was drilled to a total depth of 13,000 ft. The rotating speed was gradually reduced to approximately 300 r.p.m. at a depth of 12,375 ft., the point at which continuous coring began. The results in general of this high-speed test, considering the straight hole obtained, have definitely indicated the advantages that can result from proper application of rotating speeds as great as 600 r.p.m.

It is probable that rotating speeds of 700 r.p.m. or higher will be used in isolated cases during the coming year, although it is impossible to predict what the results may be. The companies using these high speeds are trying to determine the practice that will drill straight hole as rapidly and as economically as possible. The use of high rotating speed alone will not accomplish the desired result. It must be coördinated with other factors such as weight carried on the bit and the limitations of the equipment available to operate at high speed with safety and economy. The formations being drilled will have a definite influence, for the speeds used in one locality may not be practicable in another.

Changes in equipment design to meet the requirements of high rotating speed will probably be made to keep pace with the demand, as equipment manufacturers have always shown a willingness to cope with any problem that arises. This is no small factor, because safe and efficient operation of the equipment is of vital importance in high-speed rotation. Rotary machines used for high-speed rotation have usually been rated at 350 r.p.m., so it is obvious they have been overloaded. Bits will be subjected to severe service and, in rock bits, the bearings must withstand the speed and weight applied.

The use of a prime mover direct-connected to the rotary machine is essential for high rotating speed. Present engines are capable of providing any required speed but the mechanism for direct-connected drive may have to be further developed. Steam engines or electric motors are both being used to drive the table. The underfloor location for the rotary table drive is pre-

ferred by many operators; others set the rotary drilling unit on the same level as the derrick floor. When steam-power is used, the horizontal, twin-cylinder engine is probably best adapted for the underfloor drive; the vertical, twin-cylinder engine for the derrick floor drive. The 12-in. by 12-in. "twin" is the largest engine used for either purpose to date. One operator is thinking seriously of putting in a larger engine solely for driving the rotary as soon as other essential pieces of heavy-duty equipment for the rig can be developed.

An important factor in high-speed drilling (except, of course, in slant-hole drilling), is the control of verticality. It has become general practice in California to maintain every well as near the vertical as possible and the allowable deviation from vertical has been constantly reduced. One company has set a deviation of one-half degree as the maximum for surface hole. Below the surface string any inclination shown by deviation records of tests taken at frequent intervals is corrected immediately. Vertical hole, in the opinion of one operator, is the foundation of all drilling operations and not the result of these operations.

An important factor now widely recognized, in obtaining a vertical hole, is concentration of the weight at a point as near the bit as possible. To do this, long drill collars have become the vogue, especially in deep wells. One company operating at Rio Bravo has been using six 7¾-in. by 60-ft. drill collars suspended on 4½-in. drill pipe. Only the weight of the drill collar assembly is on the bit while rotating, the entire drill pipe being in tension. Other companies sometimes use shorter drill collars of larger diameter when the size of hole permits.

A 360-ft. or 240-ft. drill collar, however, has considerable flexibility; even when stabilizers or reamers are placed at top and bottom there may be a tendency to whip in the length of drill collar itself. One suggestion has been to place a stabilizer midway on the drill collar to prevent whipping. The neutral point, or point where the pipe is in tension above and in compression below, will vary as the weight carried is changed. The most effective location for an intermediate stabilizer would probably be half-way between the neutral point established by the maximum contemplated weight and the top of the bit.

A drill collar sleeve made of lead is being used in several fields. This equipment consists of lead cylinders placed around a joint of drill collar of the same size as the drill pipe and enclosed in an outer steel sleeve. The sleeve rests on a shoulder at the lower end of the joint but can slide upward over the pipe if a tight place or obstruction causes it to hang up. The object is, of course, to provide greater weight at the bottom of the string by use of lead.

Drill Pipe and Casing

Alloy-steel drill pipe having higher yield point than grade D has been used for several deep wells. One 12,000-ft. string has drilled two wells and is now on its third. A tool-joint of new design has also been put into service. One string of 4½-in. drill pipe having internal and external upset joints but meeting A.P.I. full-hole tool-joint qualifications has drilled more than 10,000 ft. of hole after having seen service in four other wells where it was used for approximately 9000 ft. in each. The total life of this string is yet to be determined.

Probably experience would reveal that many strings of drill pipe and tool joints have had longer life, still these particular strings have not reached their span; so their condition after long service in drilling to depths of about 12,000 ft. makes them of interest. In both cases, high rotating speed was maintained and by using long, heavy drill collars, the strings were kept in constant tension above the drill collar. Rather comprehensive studies on drill-pipe and tool-joint wear are being conducted by several of the major companies in California. One of the factors that must be considered is whip and it is evident that by keeping tension on the entire string whipping has been materially reduced. There is certainly an indication that by keeping a hole vertical and putting all the weight just above the bit, wear will be materially reduced.

Straightness of the drill pipe itself and checking to determine internal causes of failure are being given proper attention. Instruments for each of these purposes have been developed and provide for immediate corrective measures, the drill pipe frequently being straightened at the well by portable straighteners now available.

The two-string casing program is used whenever formation conditions will permit. It is the practice at Rio Bravo, where it has been used in wildcats, to carry holes to a depth of more than 12,000 ft. In a recent test, open hole was carried for approximately 11,500 ft. before the 7-in. water string was cemented 200 ft. off bottom. At Wasco a protector string is being used in addition to the surface pipe and the water string, although it is believed by some that it is possible to complete wells here with only two strings. In most of the fields of California in which drilling is relatively deep subsurface conditions make more than two strings necessary.

Surface strings are generally equipped with a guide shoe, although some conditions make desirable the use of a float shoe. Water strings for wells of any depth are made-up with a float shoe and float collar, the shoe frequently being of the whirler type. At Rio Bravo, however, many of the water strings are equipped with a float shoe and two float collars. Welded surface strings have become quite general in California; the present practice is described in a recent article.[1]

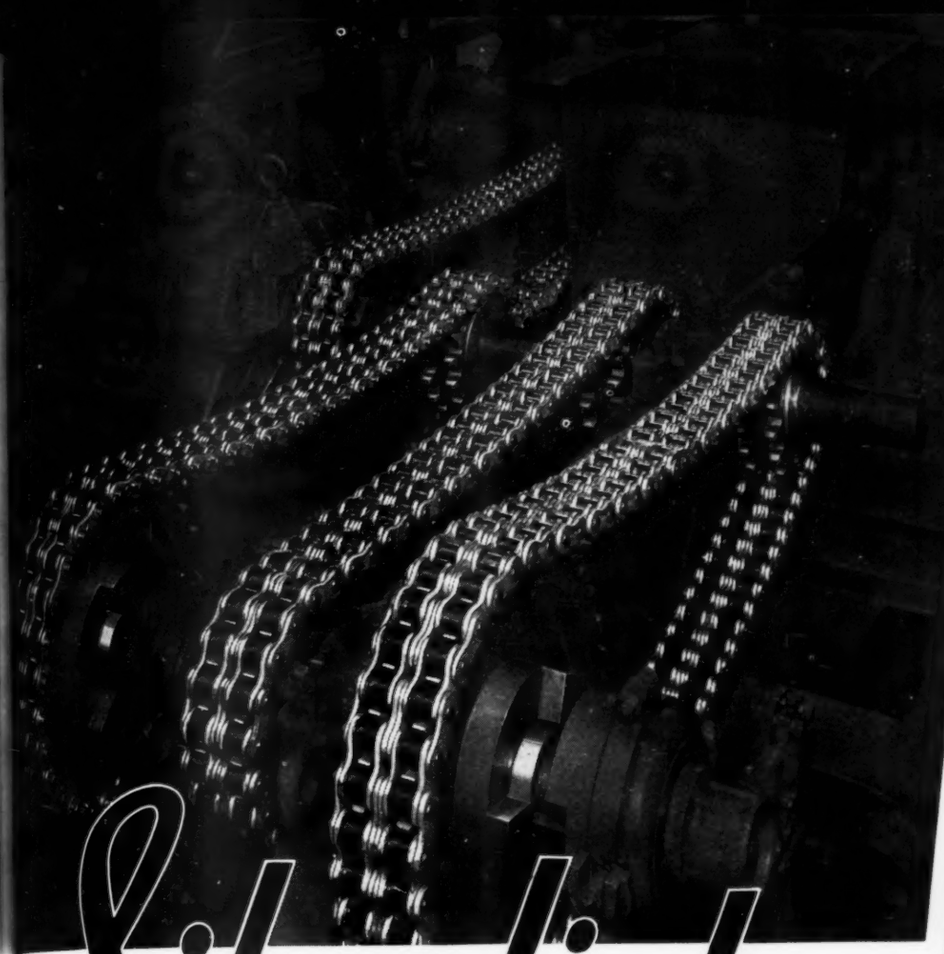
Electrical logging has aided greatly in locating markers and determining casing points. It has been particularly valuable in the development of the newer Long Beach Harbor district of the Wilmington field. Little difficulty was encountered in making correlations despite the slight subsurface variations between the Harbor district and the older portion of the field.

Drilling Mud

During the last few months renewed consideration has been given to low water loss as the primary factor in conditioning mud. This is obtained by the addition of colloidal material when the native clay is deficient in colloids. and maintaining colloidal properties by conditioning the mud during use. The extensive research work performed by a number of the companies has proved of great value. Several different formulas have been developed in which the use of chemicals has been effective in restoring the necessary properties to the drilling fluid. Chemical treatment causes dispersement and provides for carrying a higher concentration of colloidal material. Thinning agents introduced during drilling are such that they enhance the value of the colloidal properties.

In mixing the drilling fluid the materials range from the use of only native clays and water to a mixture of prepared bentonite and water. Weight material is, of course, added when heavier mud is required but usually only special subsurface conditions require the use of an excessively heavy mud. All wells drilling to any great depth, in which it is anticipated that high-pressure zones may be penetrated, are equipped with blowout pre-

[1] "Advanced Casing-Welding Practice in California," by Wallace A. Sawdon, *The Petroleum Engineer*, Dec., 1938.



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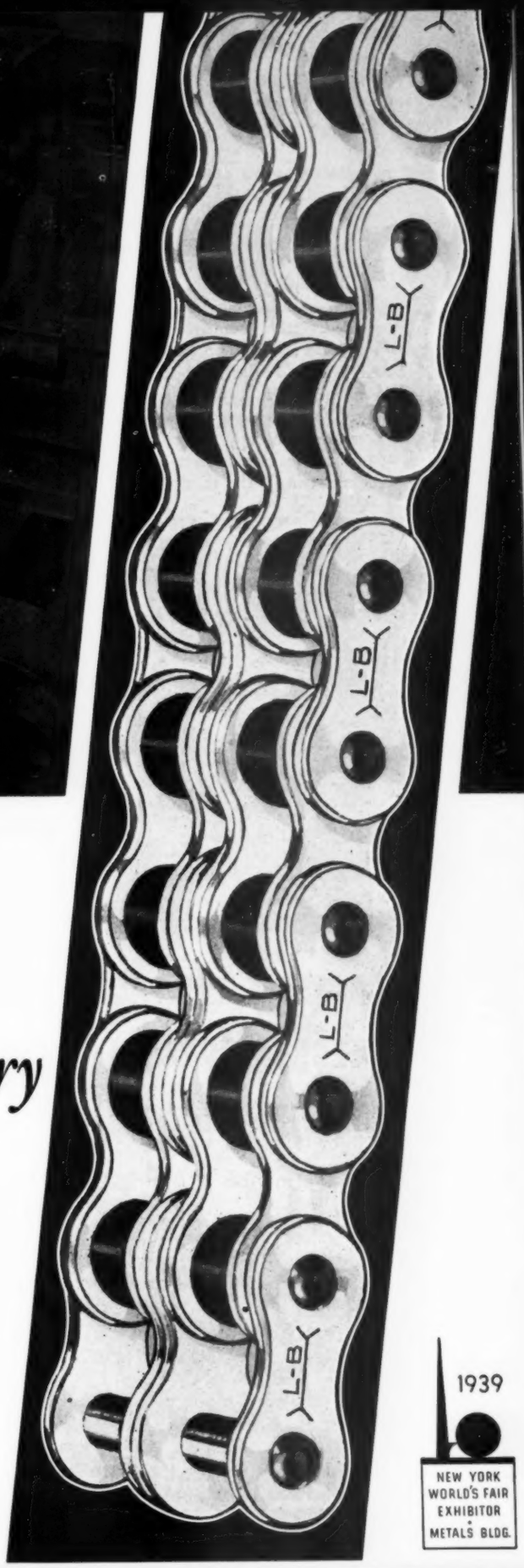

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venters or other control equipment at the surface so that any contingency may be met.

At Rio Bravo, when drilling deeper than 11,000 ft., one company uses native mud of 75 lb. per cu. ft. to which colloidal material is added as needed. Other companies occasionally weighted the mud to 82 lb. per cu. ft. At Wasco, 76-lb. mud using prepared bentonite is employed for normal drilling. When drilling through the high-pressure formation between 6000 and 7000 ft. (which is shut-off by a protector string) the mud weight is increased to 95 lb. per cu. ft. In the discovery well at Wasco mud of 100 lb. per cu. ft. was used. At Greeley 76-lb. mud made with native clay is used except when shale trouble necessitates heavier fluid. The weight is then increased to 80 lb. by the addition of weight material. At Coalinga Nose some operators use a 75-lb. native mud to which colloidal material is added; others use a 92-lb. mud containing both weight and colloidal material.

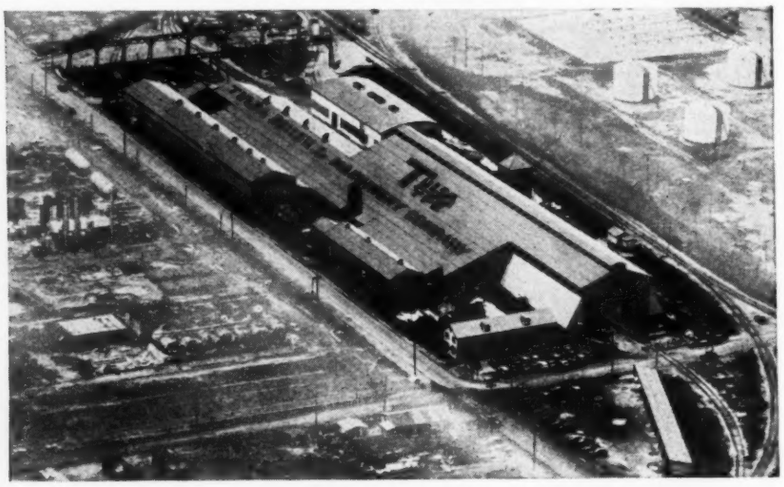
In one well recently drilled in the San Joaquin Valley it was found that tight places caused by shale formations interfered with the running of pipe while drilling. It was believed that by increasing the weight of the mud the hole could be confined by the weight of the fluid to overcome the difficulty. Weight material was added until the total weight of the mud reached 116 lb. per cu. ft., at which point tight hole was found to be eliminated. This has definitely substantiated the assertion of some mud engineers that heaving shale or other formations tending to pinch-in the wall of the hole can frequently be controlled by the use of a heavy drilling fluid; and that frequently light muds built-up to a weight of 90 lb. or more can be made even heavier (depending on the formation conditions) and produce results that can not be obtained by normally heavy muds.

When drilling through a bentonitic shale the use of weight material alone with water may be advantageous. At Rio Bravo cuttings from such a stratum increased the viscosity and gel strength of the fluid to a point where running in and out of the hole became difficult. When the fluid consisted of nothing but weight material and water the bentonite from the formation provided more than enough colloidal material so that chemical thinner could even be used to advantage.

A mixture of chemicals and colloidal mud conditioner has been extensively used to reclaim cement-cut mud; when added to the mud used for drilling-out cement it prevents flocculating and thickening. In some cases this substance is mixed to pre-treat the fluid before it is contaminated; in others it is used to treat the cement-cut mud by neutralizing the calcium ion contained in the fluid as a result of contact with the cement.

Proper conditioning of the mud during drilling is being practiced to an increasing extent in California and many of the companies provide testing cabinets in the field to insure continuous mud control. The equipment used is designed to test and aid in conditioning mud that will meet the A. P. I. standards as established at the New Orleans meeting last May. Briefly, these standards are based on the following equipment and methods:

Density—determined with Braun "Mudwate" Hydrometer, Jones Mud Balance, or bucket and spring balance; *Viscosity*—measured with Marsh Funnel, 1500 cc. in and 1 quart out; *Sand content*—elutriation method with constant head; *Wall-building test*—using filter press, 600 cc. under a pressure of 100 lb. per sq. in., reporting temperature and water loss in cc., cake thick-



CAPACITY AND FACILITIES FOR BUILDING HIGH PRESSURE VESSELS FOR PROMPT DELIVERY GASOLINE PLANT AND REFINERY EQUIPMENT

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ness to the nearest 1/32 in. for 30 min., run at 100 lb., filtering area 7.07 sq. in., using filter paper; *Hydrogen-ion determination*—using calorimetric or electrometric method; *Shear strength*—with sherometer consisting of thin duralumin tube, results expressed in lb. per 100 sq. ft., first reading after 5 min. agitation, second reading after period of quiescence.

Cementing

No serious trouble has been experienced in cementing the long strings of casing used in the deep wells. Every precaution is taken to eliminate hazards but attention is also given to increase the efficiency of the job. One company at Rio Bravo recently cemented an 11,528-ft., 7⅝-in. water string using 2500 sacks of cement in what is probably record time. The mixing time was 40 minutes and it took but 13 minutes to "bump the plugs." It is believed by this operator that fast placement around the shoe helps to reduce the chances of channelling.

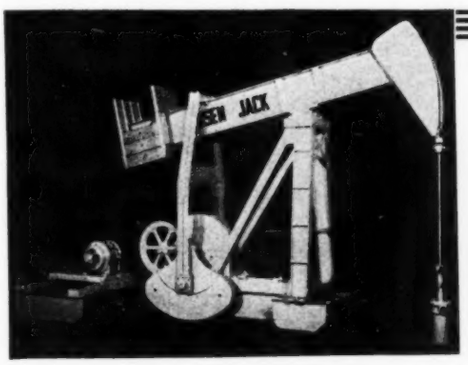
This operator also spuds the casing during the entire cementing operation. In doing this the string is raised as rapidly as possible for approximately 30 ft. and is then dropped, the performance being repeated constantly until the job is finished. Other operators in other fields are also moving the casing while cementing but not to such an extent or so rapidly. In some Kettleman Hills wells the string is moved slowly upward and downward for approximately 15 ft. and this distance is decreased to 3 or 4 ft. near the end of the job.

When large quantities of cement are being placed in deep holes it is the custom to use the slush pumps for placement of the cement. As no high pressures are necessary for this purpose the pumps are used in parallel. A new cementing head has recently been developed with three connections, two for slush pumps and one for the cement pump, to facilitate switching over to the slush pumps after the top plug is inserted. This head also provides for inserting the plugs through the top without breaking any connections.

Cementing between the zones in the Wilmington field when production from each zone is segregated has for a long time been conducted by stages using cement retainers, "duplex" equipment, "multiple stage devices", or "stacking" the liner. Recently introduced was a "series cementing method" for use either with full liner strings or with liners pre-packed with gravel.

The new series cementing method involves the use of cementing collars in the casing at the desired points. A cementing string is run into the well to position its discharge opposite each collar. Through this string the cement is pumped downward under whatever pressure may be necessary. The lowest job is cemented first, and successive jobs above are completed without pulling the cementing string from the well until all stages are finished.

The series cementing collar is constructed with whirler ports for the passage of the cement to the outside of the pipe. An inner, drillable-metal body or sleeve is securely anchored within the collar having both ends sealed to prevent by-passing of fluid or cement. Circulation holes allow passage of cement through this body into an annular chamber formed between the sleeves and collar. These holes are covered on the outside of the body by



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a rubber valve sleeve. This acts as a back-pressure valve and prevents cement that has passed through the circulation holes from returning to the inside of the collar. The cement, after passing through the circulation holes and the annular chamber, is forced from the whirler ports in a spiral motion upward and around the pipe. Downward dissipation of the cement outside the liner is prevented by the cementing basket, which protects the perforated pipe below from contamination.

The cement is transported from the surface to the cementing collar by a cementing string of tubing or drill pipe on the bottom of which is a cementing mandrel. Free circulation through the bottom of mandrel is provided until it is tripped upon reaching a point below the lowest cementing collar. The tripping is done by a bronze ball slowly pumped down the cementing string to a mating seat in the mandrel. Hydraulic pressure is then applied to release a latch; further pressure releases the tripping ball seat. The ball and its seat then slide downward until stopped by a shoulder in the bottom of the mandrel. During this travel the ball and its seat uncover circulation holes in the side of the mandrel and by blocking downward passage through the mandrel, cement is forced through the circulating holes when it is pumped down the cementing string.

The cementing string is raised until the mandrel passes through the cementing collar; it is then lowered until the latch seats on the upper end of the collar. At this point the circulating holes in the mandrel line-up with those in the collar. Mandrel seals above and below the circulation holes insure that the cement pumped down the cementing string passes through the circulation holes of the mandrel and cementing collar and out the whirler ports.

After the lowest cementing job is completed, the cementing string is raised until the cementing mandrel is above the next cementing collar above. It is then lowered until the latch positions the circulation holes opposite each other; the second cementing job is then performed. Any number of stages can be done and subsequent ones are performed in the same manner as the second. After the last is completed the cementing string is pulled out and the cement allowed to set. The inner, drillable-metal bodies or sleeves that are anchored in the collars by concrete are then drilled-out and the well is completed.

Low-Pressure Sand Completions

The general practice in completing wells in low-pressure sands is to bring the well in as rapidly as possible so that the mud is in contact with the walls of the hole for the shortest time. Completions with oil as the circulating fluid are frequently made. The most recent innovation has been the use of gas with the oil and the application of pressure-drilling methods for low-pressure completion.

Two wells in Signal Hill were completed in this manner. Both wells were cased using 8⅝-in. pipe set at 3800 ft. Drilling of 7⅞-in. hole using rock bits began at that depth.

One well was drilled from there approximately 900 ft. and the other nearly 800 ft. The control equipment at the wellhead consisted of a square kelly drilling head, below which was a blowout preventer or packer through which the drill pipe was stripped and below this a master gate. Gas was supplied by portable compressors at pressures that varied from 250 to 500 lb. per sq. in. Flow of oil and gas mixture was through a metal rotary hose into the kelly and downward through 3-in. drill pipe. Returns were upward through open hole and the 8⅝-in. casing and into a trap where pressure was

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DRILL PIPE PROTECTOR
Grizzly Giant Drill Pipe Protectors provide positive protection to drill pipe and casing all the way to bottom; as well as maximum wear, serviceability, and economy.
The solid rubber body is extra large and wide, and being moulded in one piece, is placed on the pipe in a manner that eliminates any expansion strain. It is made of the finest, toughest, and yet the most resilient rubber possible to produce; especially compounded to resist wear and the action of oil and grease; assuring maximum wear and long life. Streamlined construction prevents hanging up when running in the hole.
Easy to install and remove, Grizzly Giant Protectors can be used on one string after another until completely worn out. For maximum protection, serviceability, and economy specify "Grizzly Giant."
Installation is simple and easy; one man placing Grizzly Giant Protector on pipe with special installation tongs supplied for that purpose.
Driving tapered locking pin into tapered locking slots. To remove, merely drive tapered pin up and out of tapered slots.
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maintained at approximately 30 lb. Flow from the trap was into a settling tank and from there into a suction tank.

In changing from mud the hole was first washed with water; the water was then circulated out with oil of a gravity of 24 deg. A.P.I. Gas was injected into the oil stream until the desired ratio for drilling was established. The gas rate was 2,000,000 cu. ft. per day and the oil rate 20 bbl. per hr. This made a fog of the drilling fluid but the cuttings were removed by the velocity of the gas and the impingement of drops of oil. Loose sand from different strata was blown from the hole until presumably an angle of repose was reached with underlying shale beds that occurred at frequent intervals. No serious caving of sand was encountered. It was not until drilling was nearly completed that the oil was discontinued to better the condition of the hole.

By this procedure the low-pressure zones were not mudded-off and a clean-out program was eliminated. Bit wear and drilling time were reduced. Rock bits were used for most of the drilling but in the second well, reamer bits were employed to keep the hole to gauge. The conventional type of reamer could not be used because it could not be pulled through the blowout preventer. In the first well 6⅝-in. liner was run but in the second the liner size was reduced to 5¾ in. Good cutting samples were obtained and were found to check closely with the electrical log.

Surface Equipment

There is a definite trend toward the use of more powerful rig equipment in the development of extremely deep fields and, although some of the heaviest designs are already in service in a number of California fields, there is a possibility that even larger rigs will be employed when wells deeper than those now producing are drilled. It is ostensibly with the idea of preparing for deeper drilling that extremely large equipment was recently installed by Superior Oil Company at Rio Bravo but there is a possibility that this equipment may be found most efficient for present maximum depths.

One operator has contemplated using a derrick 225 ft. high but there now seems to be little chance of this happening. The 178-ft. derrick having a 32-ft. base will accommodate 120-ft. stands of drill pipe and it is doubtful if any longer stand would prove practicable. Two fingers have to be used with the 120-ft. stands to eliminate the sag. The flexibility of drill pipe smaller than 4½ in. is too great to make even 120-ft. stands advisable. The large floor space provided by the 32-ft. base is advantageous and the placing of the rotary drive under the derrick floor increases the available space. For relatively deep drilling, however, the 136-ft. derrick is used and for shallower wells the 122-ft.

Derricks having extended legs provide ready access to control equipment and reduce cellar depth. These derricks raise the floor approximately eight ft. above ground level and allow for most effective use of steel sub-structures and fabricated steel bases for engines and drawworks. The entire area beneath the derrick floor is usually covered by a concrete slab using a greater depth of concrete for support of load-bearing structural members.

Control equipment at the wellhead has become virtually universal and on the deeper wells usually includes two

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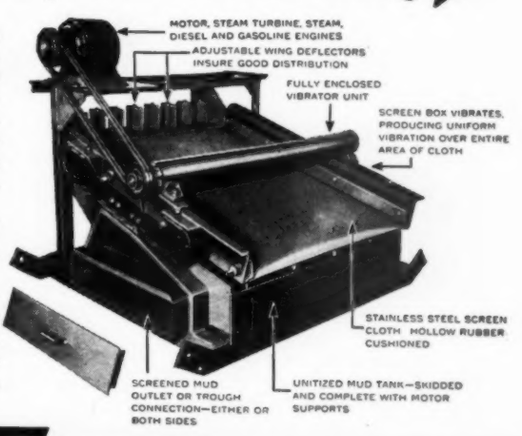
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STAINLESS STEEL SCREEN CLOTH HOLLOW RUBBER CUSHIONED
SCREENED MUD OUTLET OR TROUGH CONNECTION—EITHER OR BOTH SIDES
UNITIZED MUD TANK—SKIDDED AND COMPLETE WITH MOTOR SUPPORTS

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gates as well as a blowout preventer. Remote control of the equipment permits operation beyond the derrick floor area in case of emergency. Some operators also have a packing assembly available on the derrick floor for emergency installation on the well to provide for operations under pressure if the contingency arises.

Probably the outstanding development in the last few months has been the use of 500-lb. steam at a well at Rio Bravo. A general description of the boiler installation and machinery operated by this high-pressure steam has been given previously[2] and details of performance will be given as soon as data are available. The 350-lb. boiler has come into general use for heavy-duty operations throughout the state but 250-lb. pressure is still used for many operations. Super-heat is generally used in most of the higher pressure types, superheaters being both separate or built integral with the boiler.

Drawworks on the deeper wells are necessarily of the heavier type. Taller derricks have required more line to be spooled and larger diameter line has been provided. Both 1⅛-in. and 1¼-in. lines are now used generally and the use of 1½-in. line is contemplated. The use of the 1½-in. line will necessitate a different design of drawworks. This size line also will require crown and traveling block sheaves of special design. Brake rims to 54 in. are now in service and on many of the wells now drilling the hydromatic brake is used. On some, the double type at one end is installed and on others a single brake is placed at each end. Automatic catheads are widely employed.

The largest pumps ever to be used for mud circulation were recently installed at Rio Bravo. These are 15½ by 9¼ by 22 and are powered by 500-lb. steam. The capacity of these pumps made it advisable to use a 5-in. rotary hose to obtain full benefit from their performance. The largest pumps other than these are 15½ by 8½ by 20 using 350-lb. steam. Pump pressures to approximately 4000 lb. per sq. in. can be built-up by compounding. The use of line blinds has facilitated compounding the pumps when higher pressures are necessary. At the greatest depths now being drilled the pressure seldom exceeds 1200 lb.

Flooded suction has been found advantageous and some pump installations are made with the suction under a hydrostatic head. This is facilitated by the high derrick floor. Mud storage also is being provided by tanks usually set a short distance from the rig but elevated to allow the mud fluid to gravitate to the pumps. Mixing and addition of admixtures are in a pit and the prepared fluid is then pumped to the tank for use when needed. Degassers are built when necessary.

The 14 by 14 twin-cylinder engine is extensively used for powering the drawworks on deep-drilling operations but one specially designed 15 by 14 operating on 500-lb. steam is now in service. Engines in size to 12 by 12 twin-cylinder are being used for rotary drive and for standby units and, although larger engines for these purposes have been contemplated for some time, none has yet been installed.

The octagonal kelly has provided advantages in giving larger fluid areas and is asserted by one operator to aid materially in high-speed rotation by decreasing vibration of the drill pipe. Most octagonal kellys are being used with drill pipe larger than 4½ in. diameter and the square kelly with 4½-in. and smaller drill pipe.

[2] "Heavy-Duty Surface Equipment for Deep Drilling Being Tested in California." *The Petroleum Engineer*, March, 1939.

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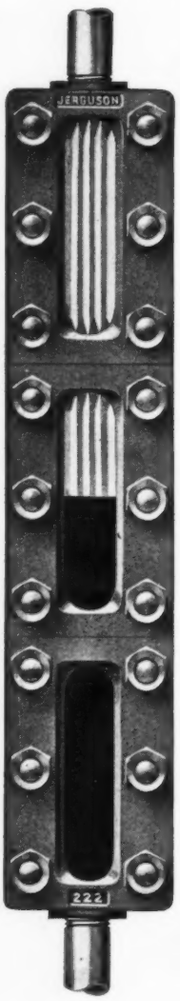

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Vapor Recovery to Construct New Office Building

The Vapor Recovery Systems Company has completed plans for a new office building at its present location, 2820 North Alameda Street, Compton, California. A modernistic structure two stories high will be constructed, having a floor space of approximately 4000 sq. ft. This will be divided into elaborate private offices, display room, reception room, large general office, engineering department for 12 engineers, and an art and advertising section. Two large fireproof vaults will preserve valuable drawings and documents.

Modern equipment will include intercommunicating systems, air-conditioning, addressograph, multigraph, mimeograph, and other business machines.

Walter F. Perkins Elected Director Koppers Company

Walter F. Perkins, vice-president of Koppers Company in charge of Baltimore operations, has been elected a

WALTER F. PERKINS

member of the board of directors.

Perkins joined the former Bartlett Hayward Company in 1915 as an assistant superintendent. He was general superintendent in 1927 when he went to the Worthington Pump and Machinery Corporation, Harrison, N. J., as works manager. He returned to Bartlett Hayward in 1932 as vice-president and general manager. He later became president, a position he held until the company, a subsidiary, was absorbed as a division of Koppers Company in 1936. He has been vice-president of Koppers Company since that time and is in charge of the Bartlett Hayward and American Hammered Piston Ring divisions, and The Maryland Drydock Company, a subsidiary. Perkins is a graduate of Lehigh University where he received his degree in civil engineering.

Honored by University

The honorary degree of doctor of science recently was conferred upon George Oenslager at the annual commencement exercises of Akron University, Akron, Ohio. Dr. Hezzleton E. Simmons, university president, also a chemist, conferred the honor. Oenslager, active in the chemical research laboratories of The B. F. Goodrich Company, has had a long and distinguished record in rubber chemical research. His greatest contribution was the discovery of organic accelerators in 1906, a development that is credited with saving the rubber industry and consumers millions of dollars annually.

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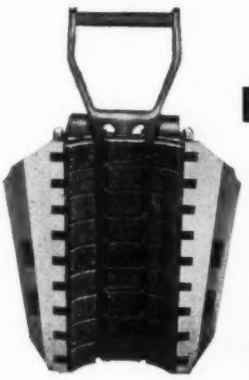

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No scarring of drill pipe and casing.

Greater strength for today's deep well drilling.

Two alloy steel pins hold inserts in each segment.

Greater flexibility and closer pipe fit.

Rotary master bushing protected against cutting.

Even distribution of load over entire gripping surface.

Drilling mud drains back into hole, not on derrick floor.

Moderate weight.

Handles several pipe sizes by changing inserts.

Easily dismantled and serviced on derrick floor.

THE TUBING SLIP AND BOWL

Gated bowl and grooved slot permit easy application to tubing and insure correct position.

Upper bowl flange serves as shelf for slips when not engaging pipe.

Lower flange fits square of rotary table when running tubing through rotary.

Four-piece unit provides maximum flexibility. 2" and 2½" tubing handled with same segments by changing inserts.

Length and position of handles provide maximum safety.

Segments cored to drain fluid back into hole.

Positive hinges prevent slips opening to the point of difficult handling.

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L. E. Tracy Made Manager Sub-Surface Sales, Midwest Division, Oilwell Supply

LLOYD E. TRACY

Lloyd E. Tracy, since 1935 sucker-rod sales engineer with Oil Well Supply Company, Dallas, Texas, has been appointed manager of sub-surface sales for "Oilwell's" Midwest Division, comprising all oil-producing areas west of the Mississippi River but excluding California. He will maintain his headquarters at Dallas.

Tracy received his academic training at Southwest Missouri State College and the University of Missouri, following which he spent eight years with National Tube Company in metallurgical work at the Gary, Indiana, and Ellwood City, Pennsylvania, plants. This experience together with four years' service with "Oilwell" gives him a sound background for sub-surface engineering work, where an understanding of corrosion problems and the use of alloys and heat-treated steels is of paramount importance.

Appoints Sales Agent

Kibele Manufacturing Company, Dallas, Texas, announces the appointment of the Walter O'Bannon Company, Tulsa, Oklahoma, as its sales agent for Illinois oil fields and adjacent districts. J. E. Ragan is field representative for the O'Bannon organization in that area.

Ralph Belshe Meets Death by Drowning

His many friends throughout the petroleum industry will be grieved to learn of the untimely death by accidental drowning at Houston, Texas, of Ralph L. Belshe, a member of the engineering staff of the Petroleum Rectifying Company of California, Gulf Coast Division. Belshe, who was 33 years of age, is survived by his widow and two children who reside in Houston, Texas.

Allsteel Products Manufacturing Co. Changes Name

The Allsteel Products Manufacturing Company, whose trademark has been "Cardwell Allsteel," has found it necessary to change its name to Cardwell Manufacturing Company, Inc., because many customers requested the change due to difficulty and confusion in filing. This correction has become necessary from the prominent use of the trademark "Cardwell Allsteel" on advertising matter and literature, which caused confusion both among file clerks and others.

"The Seal That Licks The Real Tough Jobs"

Yes, sir, plant men "in the know" will tell you that DURAMETALLIC is the outstanding packing for pumps working Hot Oil and other Petroleum products ... DURA SEAL for all Light Ends.

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M. H. French, Purchasing Agent of Guiberson Corporation

M. H. FRENCH

M. H. French, who has been on the field sales staff of The Guiberson Corporation for the last five years, covering districts in Texas and Oklahoma, has been appointed purchasing agent of the company, and will be stationed at the company's headquarters at Dallas, Texas. French attended the University of Kansas, and was with the Reserve Oil Company before becoming connected with the Guiberson Corporation.

R. P. Brown Named Secretary of Commerce of Pennsylvania

RICHARD P. BROWN

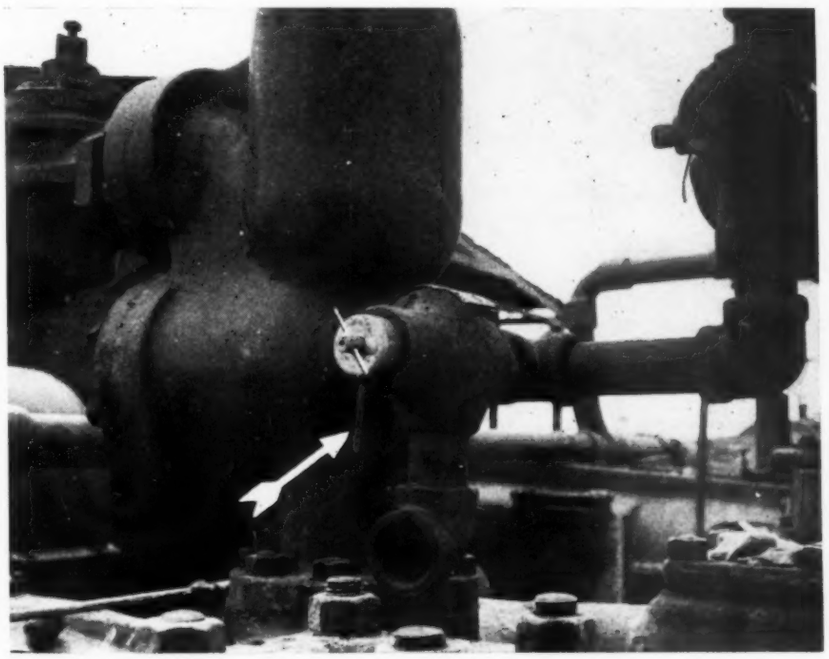
Richard P. Brown, who was recently appointed by Governor Arthur H. James to be the first secretary of the new Department of Commerce of the Commonwealth of Pennsylvania, is the former president and now chairman of the board of the Brown Instrument Company, and vice-president of the Minneapolis-Honeywell Regulator Company.

Brown has been interested for some years in the industrial development of Pennsylvania, with the objective of increasing the number of jobs in private industry and thereby reducing the relief load and, in turn, the taxes necessary to support those on relief.

Brown's past business training should stand him in good stead in his new position as Secretary of Commerce of Pennsylvania.

In New Cleveland Quarters

The Cleveland district offices of The Linde Air Products Company, Carbide and Carbon Chemicals Corporation, and Haynes Stellite Company, all of which are units of Union Carbide and Carbon Corporation, are now at 1517 Superior Avenue, Cleveland, Ohio.



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Only an ordinary wire nail, so cheap that a pound of them cost no more than 5c . . . but in this SHEAR-RELIEF Valve, it serves to protect expensive pump parts, fluid ends, and rotary hose against damage from excessive fluid pressures. When pressures reach a predetermined amount, the nail always shears, automatically releasing fluid pressures that otherwise would result in a costly pump repair job.

The SHEAR-RELIEF Valve has been proven through years of world-wide service. Ask any of the many satisfied users.

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Giant Oil-Refining Vessels Shipped to Dutch West Indies

Another shipment of giant oil-refining vessels, destined for service at Curacao in the Dutch West Indies, recently left the Milwaukee, Wisconsin, plant of the A. O. Smith Corporation. This shipment consisted of two reaction chambers, two flash chambers, and four fractionating columns, varying in size to 10 ft. 3 in. in diameter and 85 ft. 3 in. long.

All eight vessels were Smithlined throughout to resist the attacks of corrosive crudes. By this patented construction, chrome-alloy sheets are spot-welded to the steel plates at close intervals, becoming an integral part of the plates before they are formed into cylinders and heads. This lining method provides a homogeneous surface resistant to corrosion even with very thin linings, the manufacturer reports.

All the vessels were built in accordance with A.P.I.-A.S.M.E. codes. All welds were x-rayed and each tower stress-relieved and then hydrostatically tested before shipment.

The shipment was by rail to New York City, then transferred to ocean-going freighters for trans-shipment to Curacao.

A welder at work in the shell of one of the eight oil-refining vessels constructed recently for export to Curacao, Dutch West Indies

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On transmission and main lines—scattered field and gathering lines—"hot spot" reconditioning or taking up existing lines—stripping pipe—wherever you put them—Clevelands, field-tested in all soils and topography, are delivering maximum footage day in and day out, on every job.

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Another important reason why Clevelands save more is because of the low cost transportation at truck speed, via special trailer—"Clevelands" load or unload in 10 to 15 minutes.

CLEVELANDS

Revised Petroleum Films Available

With the aim of keeping its extensive motion picture film library dealing with the mineral industries abreast of scientific and technologic attainments, the U. S. Bureau of Mines has completed the revision of four petroleum films. Although the original titles remain unchanged, the revised films make available for visual-education work a fund of new information pertaining to the manufacture of gasoline, the manufacture of lubricants, the proper uses of lubricants in the operation and care of automotive equipment, and a comprehensive story of the evolution of the oil industry. Each of these four films has been revised through the financial assistance of the original coöperating companies.

U. S. Bureau of Mines film No. 99, The Story of Gasoline, takes the observer on a tour through a modern refinery and shows intricate equipment required to convert oil into motor fuel by the proper use of heat and pressure.

A somewhat similar treatment is given film No. 120, The Story of Lubricating Oil, in that it shows how lubricating oils are made, and how paraffin wax—a detrimental substance in lubricating oils—is transformed into useful products.

No. 151, Automobile Lubrication, is a one-reel film that should be used extensively in educational work by those concerned with modern methods of lubricating automobiles.

Film 153, Evolution of the Oil Industry (revised), was recently given its premiere showing at the Oil-World Exposition, Houston, Texas. Whereas the former film of this number contained three reels, the new film has been lengthened to four reels in order to show many new developments in petroleum technology in all its branches. Additional prints of films Nos. 113, 114, and 115, visualizing a journey Through Oil Lands of Europe and Africa, have been obtained to meet the steady demand for them.

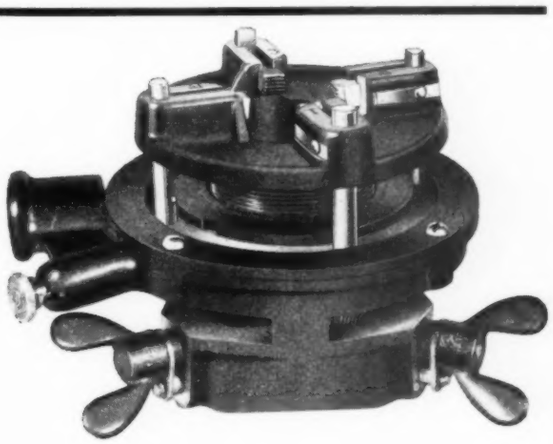
Copies of these films, which are all silent, are available in 16-mm. and 35-mm. size for exhibition by schools, churches, colleges, civic, and business organizations, and others interested. Applications should be addressed to the U. S. Bureau of Mines Experiment Station, 4800 Forbes Street, Pittsburgh, Pennsylvania. No charge is made for the use of the films, although the exhibitor is expected to pay the transportation charges.

Changes in Sperry-Sun Organization

Sperry-Sun Well Surveying Company announces the resignation of R. L. Marston, regional manager in the Gulf Coast territory, who is resuming his former production activities. Dwight C. Roberts, regional manager of the Pacific Coast territory, will be transferred from Long Beach, California, to Houston, Texas, from where he will direct and supervise the activities of both the Gulf Coast territory and the Pacific Coast territory.

Roberts is well known in the petroleum industry. He is a graduate of Stanford University and worked for a number of years as petroleum engineer for the California State Mining Bureau, and later was associated with Neil H. Anderson, California Oil Umpire, in the capacity of petroleum engineer and consultant. He is also well acquainted with the underground well surveying business through his several years association with the Alexander Anderson organization. He has been in the employ of the Sperry-Sun Well Surveying Company since the early part of 1937.

IT'S EASY ON THE BACK



. . . and it cuts a smooth, standard tapered thread that makes up tight.

The "TOLEDO" No. 1BR 1" to 2" Ratchet Threader is a favorite in the field. No bushings are used with the long life pipe holder. Three jaws each having a gripping surface of 1⅝" x ¾" hold the tool firmly with no chance to wobble or cock on the pipe thus assuring a good thread straight on the pipe.

A separate set of dies for each size pipe — assuring proper helix angle and clearance and easy cutting. 2" dies made from high speed steel.

For easy operation, smooth, standard taper threads and long life specify a "TOLEDO" No. 1BR.

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THEY'RE ALL THE SAME TO THIS PAIR!

With these two Martin-Decker Instruments on your rig you're ready for *any* kind of drilling and production work *anywhere* on a minute's notice. Easy to move and quick to install, this combination is ideal for all kinds of drilling and redrill work, and for fishing jobs, pulling tubing, and setting casing. And when you want to do some really serious deep drilling work you're still safe, because The SPECIAL has an extra large capacity — *sufficient to handle wells deeper than any thus far drilled!*

That puts you in the clear for *any* drilling job!

The Special

And the UNITIZED MUD PUMP GAUGE has a lot to say for itself, too. It has the Martin-Decker developed retard movement that combines extreme sensitivity over the low pressure range of ordinary operations, with ample capacity to handle the high pressures of cementing, breaking circulation, etc. Containing Pulsation Damper, Diaphragm Unit and Indicating Gauge in one compact unit, this instrument is as quick to install as a bull plug, and just as easily moved!

Unitized Mud Pump Gauge

These two instruments can't be beat for all-around utility where a chart record isn't needed. So why not find out about them today? There's a Martin-Decker Service Engineer near you who will be glad to give all the dope. Or write direct!

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Book Reviews

Arc Welding in Design, Manufacture and Construction. Published by The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio. 1408 pp., 695 illustrations, 1939. Price $1.50 in U.S.A., $2.00 elsewhere, postage prepaid.

Dedicated to scientific progress of arc-welding, this book is a compilation of comprehensive studies by men who are acknowledged leaders in their fields. Included are 109 pages by 126 authors covering the use of arc-welding in applications such as automotive, aircraft, railroad, watercraft, structural, furniture and fixtures, commercial welding (automotive repair, welderies), containers, machinery, and jigs and fixtures. Generally they disclose design, fabrication and construction, including the calculation of stresses and loadings, and an estimate of the cost of materials and of welding.

* * *

The Examination of Fragmental Rocks, by Frederick G. Tickell. Revised edition. Published by Stanford University Press, Stanford University, California. 154 pp., 1939. Price $4.00.

A thorough treatment of the various phases of work comprising the physical examination of clastic sedimentary rocks and of other crystalline aggregates. In revising the book, the author has rewritten the chapter on porosity and permeability to include recent advancements in the methods by which these two important physical attributes are determined. Revised, too, is the biblography pertaining to literature on the general subject of mineral analysis. Other chapters cover in detail preparation of specimens, identification of minerals, size analysis, and description of minerals found in sedimentary rocks.

* * *

Geology of the Oil and Gas Fields of the Tidioute Quadrangle, Pennsylvania, by S. H. Cathcart, R. E. Sherrill, and L. S. Matteson. Published by Department of Internal Affairs, Harrisburg, Pennsylvania. Bulletin 118 (Advance Report), 14 pages, 8 maps, 1938.

This bulletin is a preliminary report on the topography, stratigraphy, structure, and oil and gas reservoirs of the Tidioute quadrangle. The thickness, structure, and distribution of each productive sand are shown in detail on the maps and also are tabulated and described. Numerous well logs are included.

* * *

A Modern Spanish-English and English-Spanish Technical and Engineering Dictionary, by R. L. Guinle, G.C.E., F.I.L. Published by Chemical Publishing Company, 148 East Lafayette St., New York. 311 pages, 1938. Price, $4.00.

Included in the two dictionaries are the words used in civil, mechanical, and electrical engineering and most of the words used in aviation, radio, architecture, railway and automotive engineering, shipbuilding, chemistry, physics, mathematics, geology, mining, metallurgy, surveying, geography, commerce, agriculture, textile manufacture, machine tool manufacture, and various other industries. The book was not compiled for the benefit of petroleum engineers, but the volume should be useful, nevertheless, because of the inclusion of all general technical words.

* * *

Practical Accounting for Oil Producers, by Robert M. Pitcher. Published by Mid-West Printing Company, 415 East Fourth St., Tulsa, Oklahoma. 400 pages, 1938. Price, $5.00.

This volume is a non-technical text and reference book pertaining to the specialized field of accounting. An appendix includes a glossary of oil-field terms, portions of the A.P.I. uniform accounting system applying to production, and

examples of contracts. Various forms are illustrated and explained. The book should be helpful to the operator who finds accounting difficult, to the accountant who needs data for special cases, and to all men in the accounting department.

* * *

Handbook of Petroleum Accounting, by Raymond Walter McKee, C.P.A. Published by Harper and Brothers, 49 East 33d St., New York. 496 pages, 1938. Price, $5.00.

In this book is presented a comprehensive study of petroleum accounting in all its aspects. Operating procedures and detailed accounting methods used by oil companies, large and small, are illustrated by carefully selected sample forms. The book contains a detailed discussion of accounting procedure for the producing division, pipe line division, refining division, gas and natural gasoline division, marketing division, and marine and terminal division; it includes a comparison of the financial structures of American companies; discusses problems of financing and methods of preparing monthly operating reports, and supplies a condensed statistical and operating report for executives.

* * *

Physical Constants of Hydrocarbons, Vol. I. Paraffins, olefins, acetylenes, and other aliphatic hydrocarbons, by Gustav Egloff. Published by Reinhold Publishing Company, 330 West 42nd St., New York, N. Y. (American Chemical Society Monograph 78) 403 pages, 1939. Price $9.00.

The newest data pertaining to melting point, boiling point, specific gravity, refractive index, and other constants of the aliphatic hydrocarbons have been assembled and evaluated and a detailed tabulation of these constants prepared, incorporating the accepted values, whether long-established or recently determined. Volumes to be published later will include the same data pertaining to cyclic and aromatic hydrocarbons and will correlate these data.

* * *

Lexicon of Geologic Names of the United States, U. S. Geological Survey. Obtainable from Superintendent of Documents, Washington, D. C. 2396 pages (in two parts) 1939. Price, $2.50.

All names applied to geologic formations in North America, Central America, West Indies, and Hawaii have been listed in alphabetical order and the age of each formation stated. In addition, each formation in the United States and Alaska is defined and the present status of the name explained. Doubtless many operators will be surprised to learn that virtually every formation cut in drilling a well anywhere in the United States has already been named and that a name once used is not available for identifying other formations unless it has subsequently been abandoned.

* * *

Portland Cement, by Richard K. Meade. Third Edition. Published by Chemical Publishing Company, Inc., 148 Lafayette Street, New York, N. Y. 707 pages, 1938. Price, $10.00.

This comprehensive volume on portland cement has been revised and augmented by the inclusion of some new material. It now includes the latest available information concerning the manufacture of cement and the methods of analysis and physical testing of cement.

* * *

Fundamentals of the Petroleum Industry, by Dorsey Hager. Published by McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York, N. Y. 445 pages, 133 illustrations, 1939. Price, $3.50.

This book presents an introduction to all phases of the petroleum industry, including effective methods of management and engineering in the production and marketing of oil. It covers not only the essentials of oil-field operation but also history and scope of the industry, financial aspects, prospecting, transportation, and refining of oil.

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E. P. Martin Heads New Cooper-Bessemer Office

The Cooper-Bessemer Corporation, manufacturer of gas and Diesel engines and compressor units, has announced the opening of a new sales office at 314 Louisiana Street, Corpus Christi, Texas. Earl P. Martin has been placed directly in charge of this office. Martin is a graduate of the College of Engineering at the University of Kentucky. Soon after receiving his degree in mining engineering in 1924, he joined the Foxboro Company as sales engineer, serving in this capacity both in Tulsa, Oklahoma, and Houston, Texas. In 1931, he became affiliated with the Montana Power and Gas Company of Butte, serving in its gas measurement department. After slightly more than three years with the power and gas company, he returned to the sales field as sales engineering representative for the Pittsburgh Equitable Meter and Merco-Nordstrom Valve companies, being variously at Houston and Corpus Christi, Texas.

EARL P. MARTIN

L. G. Robinson Returns from Trip for Security

L. G. "Pat" Robinson, a member of the sales staff of Security Engineering Company, Inc., recently returned to the main office and plant at Whittier, California, after an extended trip to various parts of the country in the interests of his company. His itinerary took him through the Rocky Mountain and Canadian oil districts, where he conducted special research and survey work. Upon completion of the circuit, he returned to California and spent several months in the company's sales department at Bakersfield.

L. G. ROBINSON

After performing some special work in the San Joaquin Valley district, Robinson was on the move again, this time for Illinois in the capacity of factory representative. He established a branch office in Centralia, Illinois, and then moved to Houston, Texas, where he carried on his duties as factory representative in the Gulf Coast area.

Completing his activities at Houston, "Pat" returned to California, where he is now working out of Security's headquarters at Whittier.

Estimates Demand for Crude Oil 3,490,000 Bbl. Per Day, June-September

Demand for crude petroleum for consumption will be approximately 3,490,000 bbl. per day in the United States for the four months, June-September, 1939, it has been forecast by the Committee on Balance of Supply With Demand of the Independent Petroleum Association of America. This is a standing committee whose quarterly economic surveys have come to be considered authoritative in the industry and among state and federal conservation officials.

The figure of 3,490,000 is for the entire United States. For the territory east of California, the committee's estimate of demand for crude oil for consumption was 2,900,000 bbl. per day. These rates are higher than those that prevailed the first four months of 1939. In that period the total United States averaged 3,399,000 bbl. per day and the territory east of California averaged 2,778,000 bbl. per day. The increase foreseen is due to the fact that the season of largest consumption of petroleum is at hand.

The rates of demand forecast by the committee may be fulfilled either by current production or by that plus withdrawals of crude oil and gasoline from storage. This committee has consistently urged that provision be made in setting quotas for current production for reducing surplus stocks. Considerable headway has been made in this respect. On April 30 stocks of crude oil were 28,279,000 bbl. less than they were on the same day in 1938 and east of California the stocks of crude oil were 37,201,000 bbl. less. Gradually the industry is reducing the heavy inventories accumulated during the years when it was contending with several large fields developed before several of the principal states had perfected their waste prevention statutes and administrative machinery.

Much of the decrease in stocks occurred some time ago; recently there has been an increase, chiefly of crude oil produced in Illinois, Kansas, and Texas.

Recommendation was also made by the committee that gasoline stocks be reduced. In its last previous report, March 15, the committee recommended that total gasoline stocks be reduced to at least 70,000,000 bbl. by June 30. On April 30 there were 86,514,000 bbl., which, although somewhat less than they were a year before, were still considered excessive and considerably removed from the goal set for June 30.

The report was made by Harold B. Fell, Ardmore, Oklahoma, chairman of the committee and executive vice-president of the Independent Petroleum Association of America; Joe S. Bridwell, Wichita Falls, Texas, vice-chairman; C. M. Boggs, Kanotex Refining Co., Arkansas City, Kansas; Harry S. Moss, H. S. Moss Petroleum Company, Dallas, Texas, and Van S. Welch, Flynn, Welch and Yates, Inc., Artesia, New Mexico.

Argentine Engineer to Present Rice Lecture at A.S.M.E. Semi-Annual Meeting

Dr. Rodolfo E. Ballester, engineer and director of the Irrigation Department of Argentina, S. A., has accepted the invitation of A. G. Christie, president of The American Society of Mechanical Engineers, to present the 1939 Calvin W. Rice Lecture during the National Semi-Annual Meeting of the Society in San Francisco, July 10-15, 1939, according to an announcement made by R. F. Gagg, chairman of the Committee on Meetings and Program.

This is the **NEW B-M-W Fluid-Lifter Insert Pump**

It was "written up" rather fully in the May issue of Petroleum Engineer, page 135. But for complete information and prices, write us.

Briefly, this new B-M-W pump is unsurpassed for performance under severest conditons. It is built with a stationary plunger and reciprocating outside tube. It is installed in and removed from the tubing with the sucker rods. Where desired it is furnished with top hold-down, in which case the plunger is reciprocated in a stationary outside tube. Balls and seats are B-M-W CHROMARD (Stainless Steel) throughout, crowns being the newly developed 2-WAY NON-MAGNETIC type. Precision machine work on the plungers and fittings assures efficient and durable performance when handling low or high gravity oil from deep or shallow wells. Sand and water are handled effectively.

SOLD AT SUPPLY STORES

This new B-M-W Fluid-Lifter Pump is now obtainable at supply stores with other B-M-W Products: ● TEX TYPE Plunger Fittings and Valves; ● NEILSON Tools (Safety Sucker Rod Hooks, Tubing Hooks, Rod Elevators, Sucker Rod Sockets, etc.); ● BALLS and SEATS (made for every pumping service) including the TOWER TYPE Ball and Seat and 2-WAY NON-MAGNETIC Crown; ● COLLINS Belt Clamps; ● NU-TEX Pumps.

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OIL WELL SUPPLIES
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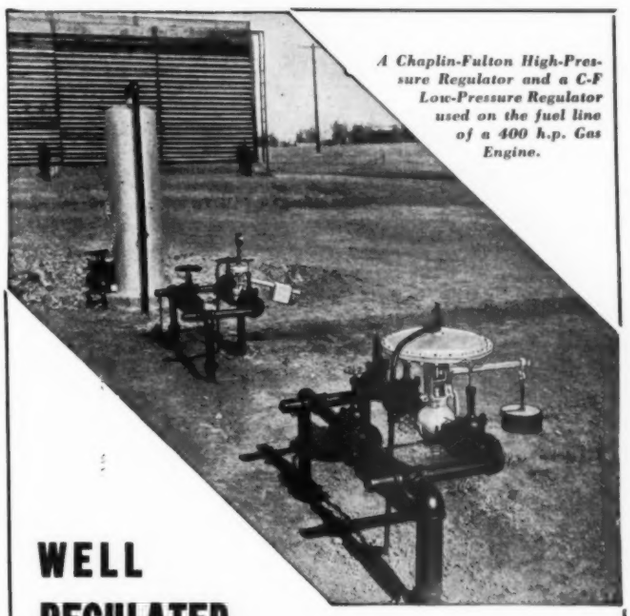

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WELL REGULATED

Chaplin-Fulton pressure-control devices for all uses have been standard equipment in the oil and gas industry for over fifty years. Ask for catalog.

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doesn't fail
YOU OIL MEN
EVEN in the mud that RIDGID adjusting nut keeps turning. And you aren't put to bother or expense replacing housings—read the guarantee! Safe chrome molybdenum jaws and comfort-grip I-beam handle. Sizes 6 to 60 in. Buy at your Supply House.
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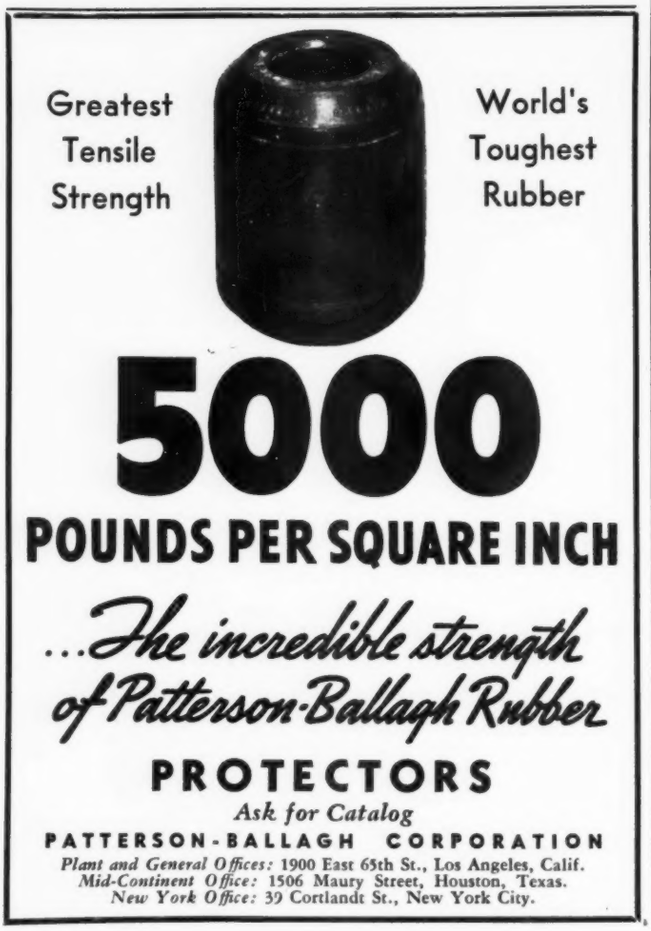
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Scientific and Technical Committee Already Working on Exhibits for Exposition at Tulsa

The Scientific and Technical Committee of the International Petroleum Exposition under the direction of Chairman Dr. Gustav Egloff, research director of the Universal Oil Products Corporation, Chicago, is already busy preparing exhibits for the May 18 to 25, 1940, show at Tulsa, Oklahoma. The accompanying photograph of a part of the members was taken at a recent meeting.

"Progress of the Oil Industry Since Drake" is the theme that will be followed by the committee in preparing its exhibits and whenever possible working models will be used. Corrosion, measuring depths, use of petroleum substitutes, drilling muds, orientation of drill holes, acids, cracking processes, hydrogenation, temperature control, core analysis, and soil analysis are among the phases of scientific development to be stressed.

The exhibits will again be housed in the Scientific Building made available for the first time at the 1938 Exposition.

Members of the committee in the photograph are, right to left, standing: R. S. Knappen, assistant to the vice-president, Gulf Oil Corporation, Tulsa; Wm. B. Way, general manager of the Exposition, Tulsa; Frank B. Long, vice-president, Oklahoma Natural Gas Corporation, Tulsa; H. M. Stalcup, vice-president in charge of production, Skelly Oil Company, Tulsa; H. R. Powers, assistant sales manager, Bethlehem-International Supply Company, Tulsa; R. L. Langenheim, University of Tulsa Petroleum Engineering School, Tulsa; M. F. Waters, president, Hanlon-Waters Company, Tulsa; and Dr. Ed Bloesch, geologist, Tulsa.

Seated are: T. E. Ronan, assistant to personnel director, Ethyl Gasoline Corporation, Tulsa; Paul S. Hedrick, oil editor, *Tulsa Daily World*, Tulsa; Dr. C. K. Francis, co-chairman with Egloff, consulting technologist and technical editor, *Oil and Gas Journal*, Tulsa; Kent Kimball, consulting geologist, Tulsa; G. H. Westby, vice-president, Seismograph Service Corporation, Tulsa; Frank B. Taylor, district editor, *Oil Weekly*, Tulsa, and J. A. McCutchen, representing C. E. Wright, general production superintendent, British American Oil Producing Company, Tulsa.

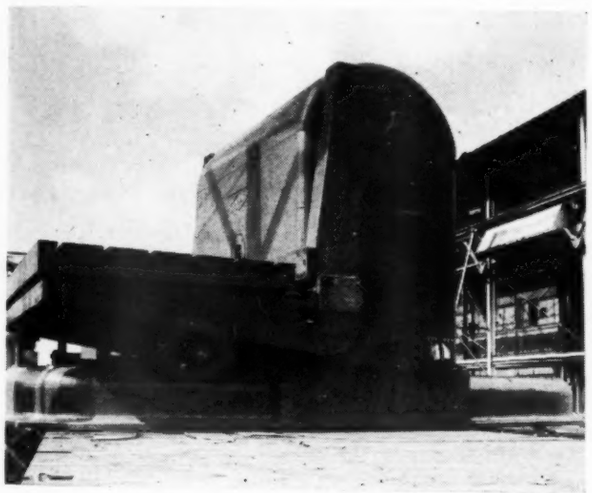
Other committee members not in the picture are: John W. Bates, contractor, Tulsa; Frank R. Clark, chief geologist, Ohio Oil Company, Tulsa; F. E. Holsten, consultant, Barnsdall Refining Company, Tulsa; J. P. D. Hull, business manager, American Association of Petroleum Geologists, Tulsa; John E. Roth, production superintendent, Tide Water-Associated Oil Company, Tulsa; Don R. Hinderliter, engineer, Hinderliter Tool Co., Tulsa; A. J. Kerr, district manager, Midwest Equitable Meter Company, Tulsa; L. W. Shank, division manager, Ethyl Gasoline Corporation, Tulsa; Paul F. Lewis, manager, American Glycerin Company, Tulsa; G. G. Oberfell, vice-president research department, Phillips

Petroleum Company, Bartlesville; W. W. Scheuman, chief chemist, Cities Service Oil Company, Tulsa; N. A. C. Smith, station superintendent, U. S. Bureau of Mines, Bartlesville; Arthur F. Truex, head of land and geological department, Sun Oil Company, Tulsa; B. B. Weatherby, president Geophysical Research Corporation, Tulsa; T. F. Birmingham, president Margay Oil Corporation, Tulsa; W. K. Whiteford, executive vice-president, British American Oil Producing Company, Tulsa; H. G. Texter, sales engineer, Spang Chalfant, Inc., Tulsa; Al Beekly, chief geologist, Mid-Continent Petroleum Corp., Tulsa; Dr. Gustav Egloff, committee chairman, director of research Universal Oil Products Company, Chicago; W. A. Schlueter, president, Refinery Supply Company, Tulsa; P. E. McKinney, metallurgical engineer, Bethlehem Steel Company, Bethlehem, Pennsylvania; Wm. F. Lowe, secretary, Natural Gasoline Association, Tulsa, and Robert H. Wood, geologist, Tulsa.

Lufkin Foundry and Machine Company Installs Large Moulding Machine

Lufkin Foundry and Machine Company, Lufkin, Texas, manufacturers of reduction gears for oil-well pumping, have recently installed what is said to be the largest moulding machine ever built of its type, and the first having all working parts completely enclosed in grease-packed housings. All guide pins are hardened and ground and operate in suitable hardened and ground bushings with provision for forced lubrication.

This machine is known as No. 66A Davenport Jolt Roll-



over Draw machine and is equipped with uniform tension cast-iron rings, and all holding pistons such as flask clamps, pattern table locking pistons, and leveling lock pistons. This roll-over mechanism operates on roller and ball bearings throughout.

The machine is completely air operated and has a lifting capacity of 12,000 lb., and the total weight is approximately 40 tons.

The largest machine built prior to this, according to the manufacturers, had a lifting capacity of 10,000 lb. and a total weight of approximately 17 tons.

This machine will be used in the manufacture of Lufkin pumping equipment.

Dudley Medal to R. W. Carlson

For his paper presented at the 1938 annual meeting of the American Society for Testing Materials on the subject "Drying Shrinkage of Concrete is Affected by Many Factors," R. W. Carlson, associate professor of civil engineering, Massachusetts Institute of Technology, has been awarded the A. S. T. M. Charles B. Dudley Medal.

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A BETTER WAY TO CLEAN HEAT EXCHANGERS

Just circulating the recommended Oakite solution through equipment routs hardened scale and carbonized oil deposits. Equipment is clean right down to the bare metal, yet without any injury to the surfaces treated.

Cleaning exchangers the Oakite way saves time because disassembling is unnecessary. Saves money, too, because higher operating efficiency is restored.

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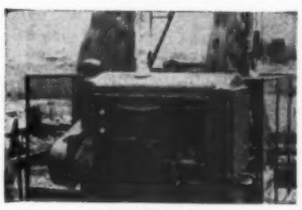
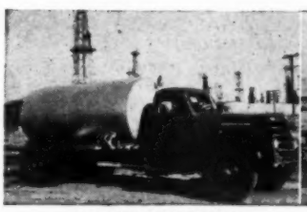
The superiority of ENSIGN Equipment for the carburetion of Butane-Propane fuels (a comparatively recent development) is just as pronounced.

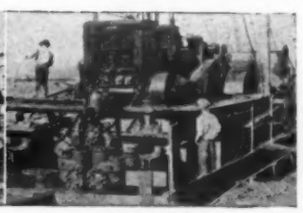
For oil well drilling servicing, pumping and transportation, be sure your engine units are ENSIGN-equipped!



PUMPING



TRANSPORTATION



DRILLING

ENSIGN [illegible]

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JUNK BASKET

The Brauer Junk Basket is a simple and efficient tool to pick up scrap iron, hammers, cones or other debris from the hole and is run on bottom of drill pipe.

By diverting the flow as indicated, the debris is lifted with the mud, and not, as in some baskets, is the junk attempted to be raised against the flow.

Once through the rubber trapping means, the junk is caught. You do not have to depend on metal clapper of fingers to close before junk can fall out.

Repairs to this tool can only entail putting in a new rubber.

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Next Houston Oil Show Announced; Refunds to Exhibitors

At a meeting of the board of directors of the Oil-World Exposition, Inc., in Houston, Texas, recently, the date for the next oil show in Houston was announced for April 11 to 18, 1942. Immediate action in selling space for the 1942 show will be taken and present exhibitors will be given an option on the same space they occupied in the 1939 exposition. This option will expire January 1, 1940, and all space not signed on definite contract at that time will be sold to applicants in accordance with the date of application. Definite action was taken after the City of Houston offered to provide additional grounds, buildings, and other facilities.

A detailed report on the achievements of the 1939 Oil-World Exposition has been made to the exhibitors by Ed G. Lenzner, general manager. This being an industry-owned,

Executive Committee, Oil-World Exposition

non-profit organization, complete data on the conduct of the show is sent upon its completion to all companies and members participating. The total gross income from sale of space, tickets, admissions, and miscellaneous sources totaled $99,871.65. As soon as all expenses have been taken care of the executive committee, upon authorization voted by the directors, will make refunds to the exhibitors.

Total attendance at the 1938 Exposition was 179,034, of which only about 12,000 was general-public attendance. Admission of exhibitors, foreign visitors, directors, and members was by badges and not included in this total. Of these badges there were approximately 5000 issued to exhibitors, 100 to directors, 300 to foreign visitors, 400 to members, and a number for special purposes.

More than 300 foreign visitors were reported and, as the export business is one of the most important to American manufacturers at the present time, the Oil-World Exposition is gratified in having been able to bring such a large number of important men from foreign countries to the Oil Show where they could be contacted in person by the exhibitors.

Attendance by important purchasers of equipment was due in part to the interest in the meetings and conventions held during the exposition. During the six days of the show there were 20 different meetings, conventions, and banquets. Additional value was given to the meetings, especially those of the Drilling and Production Committee, by the provision of printed copies of the papers delivered. These papers dealt specifically with the application of equipment to meet field and plant requirements. From 60 and 70 requests for copies have been received from men in foreign countries

who could not attend the exposition and these requested copies have been sent to them by the management.

All committees were instrumental in bringing important prospective purchasers of equipment to the Houston Oil Show. These visitors were from all parts of the United States and from various foreign countries. The committee programs included export procedure, safety in all branches and activities of the oil industry, geophysical and geological exploration, pipe-line construction and maintenance, refinery and natural gasoline plant design and methods of operation, and motor transportation in its various aspects connected with petroleum activities.

Although the desirability of having exposition-owned grounds and buildings for future oil shows in Houston was recognized, the directors voted that they would not purchase any buildings or grounds at this time but that they will coöperate with anyone who wishes to erect buildings and provide more suitable oil show facilities than are now available.

MEETINGS

California Natural Gasoline Association—July 6, Richfield Building, Los Angeles, California.

American Institute of Mining and Metallurgical Engineers, Regional Meeting—July 10, 11, 12, 13, 14, 15, 16, and 17, San Francisco, California.

Eastern U. S. Michigan Oil and Gas Exposition—August 1, 2, 3, 4, 5, and 6, Mt. Pleasant, Michigan.

Appalachian Gas Measurement Short Course—August 21, 22, and 23, Morgantown, West Virginia.

American Society of Mechanical Engineers—September 4, 5, 6, 7, and 8, New York, New York.

American Chemical Society—September 9, 10, 11, 12, and 13, Detroit Michigan.

American Institute of Mining and Metallurgical Engineers, Petroleum Division—October 4, 5, and 6, Galveston, Texas.

American Gas Association, Annual Convention—October 9 and 10, New York, New York.

National Safety Congress and Exposition—October 16, 17, 18, 19, and 20, Chalfonte-Haddon Hall, Atlantic City, New Jersey.

Independent Petroleum Association of America, Tenth Annual Meeting—October 18, 19, and 20, Fort Worth, Texas.

American Institute of Mining and Metallurgical Engineers, Petroleum Division—October 19 and 20, Los Angeles, California.

American Petroleum Institute, 20th Annual Meeting—November 13, 14, 15, 16, and 17, Stevens Hotel, Chicago, Illinois.

American Institute of Chemical Engineers—November 15, 16, and 17, Providence, Rhode Island.

American Society of Mechanical Engineers—December 4, 5, 6, and 7, Philadelphia, Pennsylvania.

International Petroleum Exposition—May 18, 19, 20, 21, 22, 23, 24, and 25, 1940, Tulsa, Oklahoma.

Third World Petroleum Congress—June 9, 10, 11, 12, 13, 14, and 15, 1940, Berlin, Germany.

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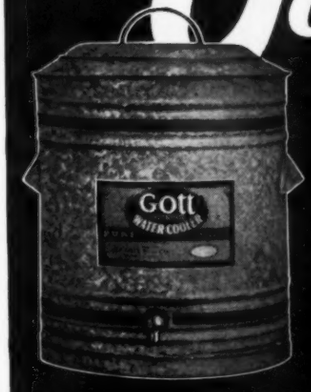

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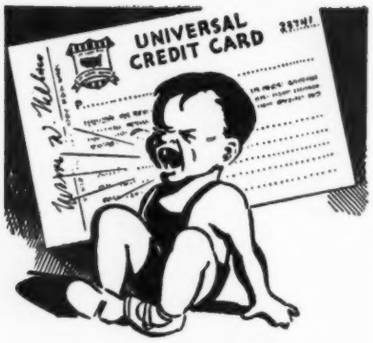

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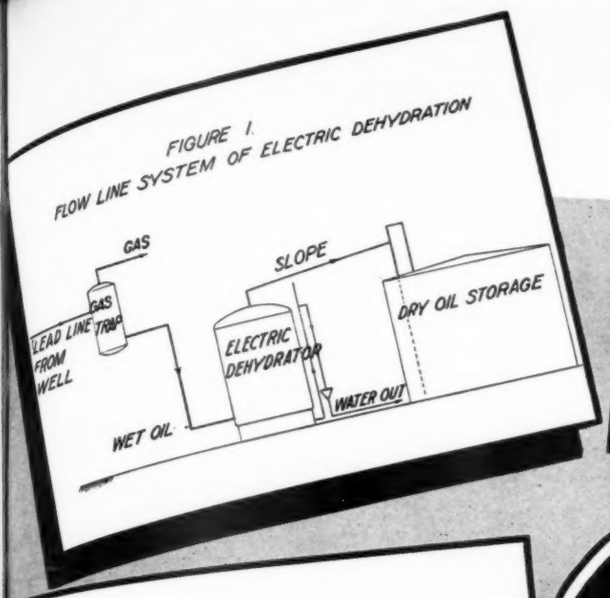

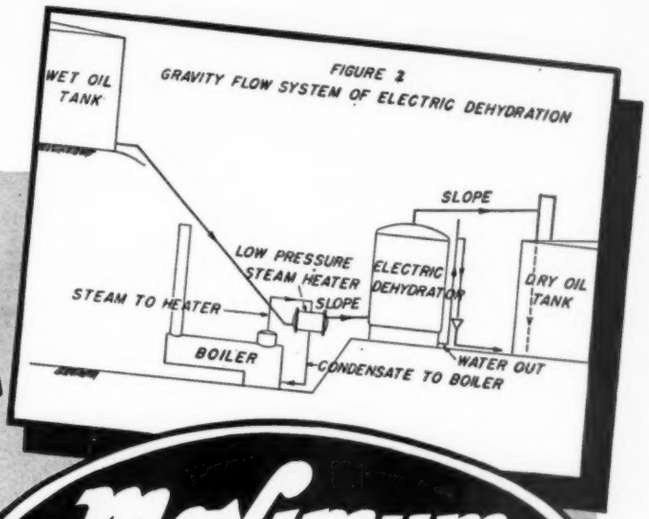

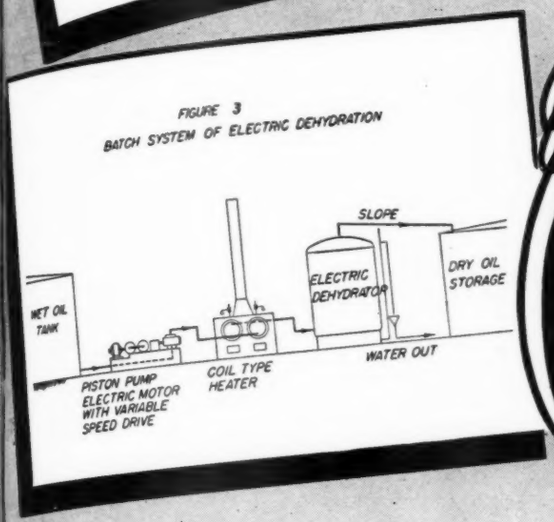

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